USE OF PLANT GROWTH REGULATORS AND GIBBERELLINS IN HORTICULTURE

I. C. A. R. TECHNICAL BULLETIN (AGRIC.) NO. 34

USE OF PLANT GROWTH REGULATORS & GIBBERELLINS IN HORTICULTURE

070

GOA UNIVERSITY LIBRARY
TALEIGAO · GOA
Donation ACC No. 070
Name of Donour L. B. Afonso.

G. S. RANDHAWA
Institute of Horticultural Research,
Hessaraghatta, Bangalore (Mysore)

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

FIRST PRINTED, AUGUST 1971

Chief Editor : P. L. Jaiswal
Editor : Dr (Mrs) A. M. Wadhwani
Assistant Editor : Rajinder Singh

Price Rs. : 3.75

Printed in India by S. R. Malhotra at the Swan Press of Lahore, 3 Chamelian Road,
Delhi-6, and published by T. S. Pruthi, Under Secretary, for the
Indian Council of Agricultural Research, New Delhi-1.

PREFACE

During the last three decades, considerable work has been done on plant growth regulators and gibberellins in the field of agriculture, including horticulture. In horticulture, the plant growth regulators and gibberellins have been used in (1) rooting of cuttings, (2) control of pre-harvest drop in fruit crops, (3) flower thinning, (4) control of flowering, (5) fruit setting and parthenocarpy, (6) inhibition of sprouting in some vegetable crops in storage, (7) weed control, and (8) in breeding. Gibberellins are being commercially used for increasing the berry- and bunch-size and also in production of grapes, especially the seedlesss varieties.

Intensive work on plant growth regulators and gibberellins was started in India under the All-India Co-ordinated Scheme of the Indian Council of Agricultural Research to study the effect of application of growth-regulating substances in horticulture, with two centres, one at Patiala (Punjab) and another at Kodur (Andhra Pradesh). This scheme was started in 1956 and was terminated in 1963 and very good work was done under this Scheme. In addition, considerable work on fundamental aspects of auxins and gibberellins was done in various Indian universities and recently in various agricultural universities all over the country and at the Division of Horticulture in the Indian Agricultural Research Institute, New Delhi. In January 1967, a Symposium on Plant Growth Substances was held by the Department of Botany, Calcutta University under the auspices of the University Grants Commission. A large number of papers on various aspects of plant growth regulators and gibberellins were presented to this Symposium. In December 1967, the Horticultural Society of India held an International Symposium on Subtropical and Tropical Horticulture and one of the subjects selected for this Symposium was the use of plant growth regulators and gibberellins in horticulture. Again, a large number of good papers were presented in this Symposium. It is thus evident that considerable work on plant growth regulators and gibberellins is being done in the country. As the new chemicals are being constantly developed, it is necessary to try them also with various horticultural crops for specific purposes. With the establishment of the Institute of Horticultural Research at Hessaraghatta by the Indian Council of Agricultural Research, considerable work is proposed to be done on plant growth regulators and gibberellins in fruits, vegetables and ornamental plants. A section of plant Physiology and Biochemistry has been established in this Institute to take up work of this type. It was, therefore, considered necessary to review the work done on plant growth regulators and gibberellins, not only in this country but also abroad, which could be of great help to the research workers and the post-graduate students in various universities and institutes.

The present technical bulletin on 'Use of Plant Growth Regulators and Gibberellins in Horticulture' covers nine chapters dealing with various uses of this group of chemicals in horticulture. At the end, important references on various subjects have been given chapter-wise. It is hoped that the information contained in this bulletin would be of use to the research workers as well as the post-graduate students.

The author is grateful to Dr R. K. N. Singh, formerly Pool Officer in the Indian Council of Agricultural Research, now Horticulturist, Nagaland and Shri R. R. Kohli of the Institute of Horticultural Research, Hessaraghatta for the help in the preparation of this technical bulletin.

G. S. RANDHAWA

CONTENTS

		PAGE
	Preface ...	v
I.	Role in Plant Propagation ...	1
II.	Effect on Flower Initiation, Fruit-set, Yield and Quality ...	14
III.	Control of Pre-harvest Drop ...	24
IV.	Flower Thinning and Control of Biennial Bearing ...	38
V.	Herbicidal Action of Plant Growth Regulators ...	48
VI.	Role in Plant Breeding ...	57
VII.	Sprout Inhibition in Some Vegetable Crops ...	65
VIII.	Chemical Induction of Parthenocarpy in Fruits and Vegetables ...	70
IX.	Gibberellins ...	82
	References ...	100

CHAPTER I

ROLE IN PLANT PROPAGATION

Plant propagation methods are of utmost importance in horticultural crops, especially in fruit trees. In some fruit plants, the percentage of success in asexual propagation is extremely low. It is in overcoming some of these difficulties that the growth regulators find their ready use. A greater percentage of rooting and production of more roots in a shorter time in cuttings and layers, quicker callus formation and better union in grafts and quicker and better germination, associated with a more vigorous growth in the initial stages in the case of seed treatments are the major benefits derived from the use of growth regulators in plant propagation.

PHYSIOLOGICAL, ANATOMICAL AND METABOLIC CHANGES FOLLOWING AUXINS TREATMENT

The physiological effects of auxin treatment are stimulation or in other cases inhibition of growth and development. This stimulative effect is often temporary and the ultimate increase in growth as a whole is very rare. In the formation of roots in cuttings, the first step is the differentiation of root primordia and this differentiation depends upon the proportion of auxins to certain other substances present in the cuttings. When the ratio of auxins to certain other plant constituents, especially adenine is low, the meristem of tobacco sections tend to form bud and leaf primordia ; when the ratio is medium, callus is formed, and when the auxin content is high, root primordia develop (Skoog, 1944).

Some sort of interaction between the auxin and the plant constituents to be responsible for inducing root formation was demonstrated by van Overbeek *et al.* (1945, 1946). The anatomical changes following treatment with growth substances are initiation of meristematic activity in endodermis, phloem parenchyma, ray parenchyma and pericycle tissues. Beal (1946, 1951) observed meristematic activity in the above tissues, in the stem of decapitated bean plants 24 hours after treatment with 2,4-D and immense spread of undifferentiated callus like tissue associated with swelling of the stem 72 hours after treatment. Randhawa and Thomson (1948) reported greater development of placenta and more complete filling in tomato, following absorption of growth regulator through roots.

Increase in metabolic activity, as a result of auxin treatment, has been reported by several workers. Increased rate of respiration has been observed by several workers. Associated with increased respiration and enzymatic activity is a corresponding decrease in starch reserves and acid hydrolysable polysaccharides (Commoner and Thimann, 1941 ; Leopold, 1955).

ABSORPTION AND TRANSLOCATION OF GROWTH SUBSTANCES IN PLANTS

The type and magnitude of the response to treatment with growth regulators depend upon the amount of the compound absorbed, the amount translocated within the plant and the ability of the plant to respond to the stimulus of the particular chemical used. Esters dissolved in oil and emulsified in the spray solution enter more readily than salt formulations through the waxy tissues. Also the electric charge of the protoplasm may determine whether a particle is attracted or repelled and the acidity of the sap and the nature of the cell constituents may determine the ease with which a plant may absorb a given chemical (Tukey and Krishnamoorthi, 1948). Rice (1948) has reported that absence of light and decrease in temperature reduced absorption of 2,4-D in bean plants.

Translocation of growth substances mainly occurs through water-conducting tissues. When absorbed by leaves, the growth substances are apparently translocated in the same manner as carbohydrates.

PROPAGATION BY CUTTINGS

Even though the stimulating effects of certain substances isolated from urine, orchid pollen, maize oil, etc., on the growth processes of plants were known very early in the nineteenth century, Cooper (1935) was the first to investigate the practical applications of growth regulators in plant propagation. Following his works, quite a large number of organic substances were tested for their usefulness in plant propagation practices including seed treatment and considerable success has been achieved in this field. Propagation by cuttings, including layering, has several advantages. The most important one is the maintenance of all heriditary characters of the mother plant. A very large number of fruit trees, however, do not root readily if their cuttings are planted normally. The discovery of growth regulators has now widened the scope and increased the efficiency of propagation of fruit plants and other economic plants by cuttings.

Selection and Preparation of Cuttings. The ease with which cuttings of plants root successfully is governed by several factors like (*a*) the inherent characteristics of the species or variety, (*b*) age of the tree and the shoot taken for cutting, (*c*) the nutritional condition of the parent plant, (*d*) the time of taking cuttings, and (*e*) environmental factors. The treatment of cuttings by growth substances is only a supplement to the favourable conditions necessary for the root formation and

cannot be expected to produce any great success to overcome varietal shyness of rooting and similar physiological characteristics. Cuttings of certain species root more readily if taken from young trees than from mature trees. Hard wood of most of the trees and shrubs respond less to treatment with growth substances than the soft wood cuttings. Generally, cuttings are taken from twigs of the current year which are about one year old. Chadwick (1931) has reported that the best place for basal cut is about 1.27 cm below a node in majority of the deciduous plants. Basal leaves are usually removed to enable easier treatment or insertion in rooting media. Large leaves are also removed or reduced in size. Garner and Hatcherd (1955) have reported that in three varieties of plum tested by them, cuttings taken from layered trees were superior to hedge plants and that the basal, middle and apical cuttings gave better rooting in the order indicated.

Methods of Treatment with Growth Substances. Solutions of most of the growth substances are made by dissolving previously weighed quantity of crystals in a few drops of 95 per cent ethyl alcohol which is then diluted with the required quantity of water. Salts of many of the acidic growth substances are readily soluble in water and can be dissolved directly in water. Stock solutions of some of the substances can be prepared and kept without deterioration for some weeks, if stored in a cool, dark place. The strength of the solution to be used depends upon season, nature of cuttings, species, maturity of cuttings, chemical used and certain environmental conditions. The following methods of application have been tried by different workers with varying degrees of success.

Solution Immersion Method. The cuttings held in bundles by rubber bands are set with basal ends about one inch in the solution of the root-inducing substance, which are not kept in metal containers. Solutions of IBA and NAA can be used three times if used within a week of preparation and if evaporation is reduced to minimum (Chadwick, 1937) ; while solution of IAA deteriorates more rapidly. During treatment, cuttings should be out of direct sunlight, but in good light. At night or in very dark weather, the length of treatment may be somewhat longer. Temperature also affects the length of treatment of cuttings (Tineker, 1938). Higher the temperature shorter is the duration of treatment.

Concentrated Solution Dip Method. The basal one-half inch of the cutting is dipped in a concentrated solution containing 1 to 20 mg of growth substances in 1 cc of water or a mixture of water and ethyl alcohol. This method reduces the time of treatment to a few seconds and is found as effective as optimum auxin concentration in the Solution

Immersion Method (Hitchcock and Zimmerman, 1939). This method is particularly useful in the case of cuttings which may be injured by a prolonged soaking in water or even in solution. Cooper (1944) found the concentrated solution method of treatment quite effective and more convenient than the dilute solution method.

Powder-Dip Method. This method was first suggested by Grace (1937) and is now widely employed. The basal one-half inch of the cutting, previously moistened with water, is dipped in talc with which is mixed the root-inducing substance in the required proportion. The excess of powder is removed by tapping the cutting on the inside of the container and the cuttings are ready for placement in the rooting medium.

Deferred Treatment or Re-treatment of Cuttings. Cuttings of some species may respond to treatment with root-inducing substances when taken out from the rooting medium, weeks or months after first insertion and treated without removing callus (Hitchcock and Zimmerman, 1938). Such treatments are called 'deferred' if applied for the second time. Rooting of cuttings of Hamlin Sweet Orange was improved by re-treatment with growth substance three weeks after the initial treatment. Similar results have been reported by Kordes (1943) in conifers and certain evergreens.

Spraying the Stock Plants. Stoutemeyer and O'Rourke (1945) sprayed solution of 2,4,5-TP in concentrations varying from 25 mg to 100 mg per litre on the parent trees of certain species from which cuttings were taken 9-40 days after the sparying and set in the rooting medium. The results were as good as the responses obtained when the severed cuttings were treated in the usual way. But more trials are necessary before this method is adopted in practical propagation.

Other Methods. Tinker (1936, 1938) sprayed cuttings in the propagation beds at intervals with dilute solutions of the auxins but did not get successful results. Watering the beds with very dilute auxin solutions gave some success, but was a wasteful method. Hildreth and Mitchell (1939), however, reported successful results by the spraying method used by Tinker. The lanolin paste method was used by many of the early workers, but is now used only for certain specific purposes like treatment of air-layering shoots.

Comparative Effects of Different Growth Substances in Rooting. The response to treatment with different growth substances varies with species, the physiological state of the cutting, the rooting medium and similar factors. The most commonly used substances are IAA, IBA, NAA and NAD. In many trials conducted to test the effectiveness of various growth substances in rooting, IBA has been found to be more effective than IAA or NAA and also with a wider range of effectiveness, without causing damage to cutting. Cooper (1940) also found IBA superior to IAA and NAA. Hitchcock and Zimmerman (1939) and Kirpatrick (1939) observed that NAA was superior to IBA for cuttings of some species.

Besides the compounds mentioned above, several other phenoxy compounds and their halogen-substituted derivatives possess root-inducing properties to varying degrees. Grace (1939) tested the activity of a number of naphthalene acids with regard to their influence on rooting of cuttings and found that activity existed up to and including naphthalene hexoic acid. In a later paper (1940), he reported that naphthalene butyric acid and potassium naphthalene hexoate were as effective as NAA or IBA. Among the phenoxy compounds tested by Zimmerman and Wilcoxon (1935), the following were found to be active growth substances in the order of potency : (1) α-naphthalene acetic acid, (2) β-naphthalene acetic acid, (3) acenaphthyl-5-acetic acid, (4) indolebutyric acid, (5) phenylacetic acid, (6) anthracene-acetic acid, (7) C-naphthyl acetonitrile, and (8) indolepropionic acid.

Substances Aiding Root Formation. Certain substances, though not active growth substances, have been found to aid root formation in cuttings. Treating cutting with vitamin B_1 or vitamin B_1 and B_6 separately after treatment with growth substances or along with the growth substance have been reported to be beneficial for rooting by several workers. Similarly, carbohydrates, amino-acids and nitrogenous compounds, mineral nutrients, acetic acid, potassium permanganate and some other substances have been reported to be aiding root formation when used in addition to growth substances.

In certain cases, a mixture of two or more growth substances in suitable concentrations has been found to be more effective than any of the compounds used separately. Thus Hitchcock and Zimmerman (1940) have reported that a mixture of IAA and IBA produced better rooting response than when either of them were used separately.

Work Done on Major Fruits. Work done on major fruits is discribed below.

Deciduous fruit. Soft wood cuttings of *Prunus cerasifera* made in the spring, from terminal shoots, rooted 100 per cent after treatment with NAA (30 mg/1) as compared to 20 per cent in control. In pear, untreated cuttings of most common varieties did not root, but treatment with NAA (40 mg/1 ; 12 hours) gave 100 per cent rooting in spring and 75 per cent in early spring in some varieties (Pearse and Garner, 1937). Favourable results of treatment with IBA and IAA on pear and cherry cuttings have been reported by Brase (1938). With several varieties of apple, the treatment was not successful. Yorkes (1938) also obtained favourable results with IBA treatment (50 mg/l : 5 hours) on *Prunus triloba* cuttings. Watkins (1938) treated cuttings of Hood pear variety with Hoomodin A (contains IBA) and obtained 100 per cent rooting in three weeks. Dostal (1942) successfully tried a new method of treating apple cuttings (Cox's Reinetta) with auxin, as the usual method was ineffective. The shoots were ringed to a width of 1 to 1.5 cm and the exposed ring was wrapped around with filter paper, the ends of which were dipped in flasks containing 0.00005 per cent IAA solution. A healthy callus was formed and after wintering, the shoots developed buds and roots.

Sinha (1942) used IBA in lanolin paste on the basis of layer shoots of Pershore plum and pear but could not get any improvement in rooting. A slight improvement was obtained in Myrobalan B plum which however, roots without much difficulty even without treatment. Mohring (1943) reported a method of treating scion portions of certain fruit trees to induce root formation. One-year-old budded apple on Malling IX dwarfing stock was treated with Belvitan (containing IBA) paste, after removing a strip of three-fourths of an inch of the bark of the stem and they were planted deep, when there was satisfactory root formation. The treatment was particularly successful with Blenhein Orange, Allington Pippin, Winter Gold Pearmain and Ontario. Beneficial effects of IBA and NAA on the rooting of three varieties of plum have been reported by Dikshit (1953). Howe and Early Round gave 68 per cent and 66 per cent rooting respectively when treated with IBA (30 ppm), while the Kelsey rooted only to the extent of 20 per cent. In a further study on Kelsey plum, he obtained 25 per cent rooting when IBA was used at 40 ppm and NAA at 10 ppm. Garner and Hatcher (1955) obtained very good results by treating the Brompton root-stock plum cuttings with IBA (0.05 per cent) in solution, while there was very little response in Crab C apple. Hartman and Hansen (1958) found that IBA treatment was markedly beneficial in stimulating rooting in hard-wood cuttings of Marianna, 2,624 plum and peach root-stock No. 7, but was of no aid for Quince, which is a readily rooting species.

Mango. Thakurta and Dutta (1941) reported that the application of IBA (3 per cent) on the ringed portion of marcots of mango when wrapping and also to the base of the cuttings 24 hours before severance from the mother plant was very beneficial for rooting of cuttings from 2-3-year-old trees. From older trees, the success was much less. Singh (1954) studied the suitability of 12 varieties of mango as clonal root-stocks by air layering 2-year-old shoots on 20-year-old tree. The selected shoots were treated with NAA (1 per cent) by the lanolin paste method. The percentage of rooting obtained was as follows :

Dwarf varieties		Semi-vigorous varieties	Vigorous varieties	
Brindabani	80%	Kala 80%	Machhali	100%
Krishnabhog	40%	Anfas 70%	P.S. Special No.2	60%
Samarkand	22%	Rataul 60%	Langra Banarsi	40%
Totapari Small	20%	Dasheri 60%	Tojri Kalan	10%

Citrus. Cooper (1935) obtained quicker and more rooting in the cuttings of Eureka lemon and several other varieties of citrus by treatment with IBA and IAA compared to control. Cooper (1936) further reported that by soaking the bases of lemon cuttings in heteroauxin (0.5 mg per cc of water) for eight hours before setting in sand, a much greater number of roots was induced on treated cuttings compared to control. Gocolasvili and Maximov (1937) found that cuttings from the trifoliate orange, treated at the base with weak solutions of IAA, rooted up to 100 per cent and cuttings from Unshiu tangerine up to 70 per cent, whereas without such treatments, cuttings of these plants rooted very rarely. Marques (1938) got better rooting by using 100 and 50 ppm IAA and NAA (long dip) in case of sour orange cuttings. Baile and Halam (1938) also reported marked increase in the percentage of rooting in grapefruit and Valencia orange cuttings treated with IAA, while lemon and citron rooted just as well without treatment. Cooper (1940) and Cooper and Knowlton (1940) found a marked increase in the percentage of rooting and average number of roots per cutting in a number of citrus species by an application of 0.02 per cent solution of IAA (24 hours dip). Traub (1938), working on the sub-tropical fruits, reported a good response of plant regulator treatments in case of several species including citron and lemon.

Erickson and Bitters (1953) used NAA, IBA, 2,4-D and 2,4,5-T for rooting cuttings of citrus and related species. No single growth regulator was best for rooting of all the species, but each one was better than others in some respects for some particular species. Erickson and Debach (1953) obtained higher percentage of rooting by treating the lemon cuttings with 0.2 per cent NAA. Naundrof and Terreros (1952) reported best results by crushing the bases of cuttings combined with basal treatment with 5 mg IBA to 1 g talc powder. The percentage of rooting and number of roots per cutting, after 25 days, were 78 and 4.2, compared to 56 and 3.4 in the next best treatment and 0 per cent and nil in the control. After 50 days, the figures were 96 per cent and 14.6, 92 per cent and 11.4 and 60 per cent and 5.5, respectively. Missic and Pavicevic (1954) conducted expriments on the use of KNAA for the rooting of lemon cuttings. The lemon cuttings, which were 8–10 mm thick, 10–15 cm long with and without 2–3 leaves, were treated with 0.001 to 0.2 per cent potassium salt of NAA (Regulex) for 24 hours. The best rooting responses were obtained with 0.01 and 0.005 per cent concentrations. Higher concentrations induced more rapid rooting, but were phytotoxic, while the response to a lower concentration was insignificant.

Singh (1955) investigated the effects of a number of growth regulators on the rooting of citrus air layers. He obtained good results with IBA 1.0 per cent plus 1.0 per cent IAA in case of *kagzi* lime (*C. aurantifolia*). The percentage of rooting with the growth regulators was the same (100 per cent) as in control but an improvement in the average number, length and thickness of the roots was noticed. With sweet lime (*C. limettioides*), NAA (1.0 per cent) plus IAA (1.0 per cent) gave 100 per cent rooting compared to 60 per cent in the control and also increased the average number and length of the roots. With grapefruit also, IAA (1.0 per cent) gave the same rooting as control (100 per cent) and increased the average number and length of the roots. With grapefruit also, IBA 1.0 per cent gave the same rooting as control (100 per cent) and increased the average number and length of the roots. Dikshit (1956) also obtained best results with 250 to 300 ppm IAA (24 hours dip) which improved the rooting from 45 per cent (in control) to 65 per cent in *kagzi* lime.

Bove (1957) noted the beneficial effects of orange juice with NAA and aneurin for rooting and those of kinetin and gibberellin on initiation and growth of roots in citrus cuttings. Cailahjan and Nekrasova (1958) treated apical ends of the lemon cuttings with four growth substances alone or in combination. Rooting was induced by NAA and heteroauxin plus ascorbic acid, but no rooting occurred when TIBA or GA were used. GA induced shoot formation in both normally set and inverted cuttings. Jauhari and Rahman (1959) reported an increase in the percentage of rooting of sweet lime hard wood cuttings by the use of a mixture of 50 ppm IAA and 50 ppm NAA by the dilute solution method.

Singh (1959, 1960) conducted trials with *karna khatta* (*C. karna*), sweet lime (*C. limettioides*) and *kagzi* lime (*C. aurantifolia*). He used IBA by the concentrated-dip method. It was found that the ready rooting cuttings of young nursery plants of *karna khatta* and soft wood cuttings of *kagzi* lime were not benefited by any concentration of IBA except the semi-hard wood cuttings of *karna khatta* which required only 500 ppm IBA for effective rooting. The shy rooting subjects, namely the hard wood cuttings of *kagzi* lime did not show any improvement by IBA treatments and in all the cases the rooting was very poor. With koderate rooting cuttings of sweet lime, obtained from water sprouts and shoots from dehorned trees, an improvement in percentage of rooting was noted. A concentration of 2,000 ppm IBA improved the rooting percentage up to 70 per cent compared to control. Das *et al.* (1959) found a beneficial effect of 200 ppm IBA with 2 per cent sucrose by the solution (long dip) method on the semi-hard wood cuttings of sweet lime. By the concentrated-dip method, however, 500 ppm IBA was found to be effective for sweet lime cuttings. Singh *et al.* (1960) also worked on the cuttings of sweet lime in Punjab and obtained better sprouting and total extension growth following the treatment with Seradix A powder.

Plum. Dikshit (1956) reported that Large Red, Large Yellow and Alpha plum varieties could be propagated by stem cuttings with the help of IBA on commercial scale.

Guava. Singh (1950) studied the effects of treating guava (*Psidium guajava*) gootees with Hortomone A (¼ cc in two pints), NAA (1, 2 and 3 per cent), phenylacetic acid and Seradix 'B' powder (No. 2). He obtained 77 per cent rooting with Hortomone A, in the variety Karela, while there was no response in Allahabad Red. One per cent NAA gave 100 per cent rooting in 13 days, as against 30 days required by untreated gootees. NAA (2 per cent and 3 per cent) and all concentrations of phenylacetic acid and Seradix 'B' were found unsuitable. The work carried out at I.A.R.I., New Delhi also indicates the usefulness of IBA in air layering of guava. IBA (250 ppm) applied in lanolin improved the rooting significancy over other treatments (Godara, 1960).

Grapes. Yorkes (1938) reported that August cuttings of Muscadine grape rooted 44 per cent in three weeks after treatment with IBA (20 mg/1 ; 20 hours) compared to no rooting without treatment. Anliker and Kobel (1945), working with Riesling × Sylvaner grape variety, found that the cuttings possessing one bud were benefited by the application of heteroauxin and Roche 202 (a proprietary hormone) in respect of root formation. Shoot growth was, however, suppressed as the concentration increased. Baranova (1946) studied the effect of heteroauxin upon rooting and anatomical structure of green wood cuttings of vine (*Vitis amurensis.*). The cuttings were treated with 0.01 per cent heteroauxin. After 7–10 days, swelling occurred on the lower end of the treated cuttings, while no swelling was noticed on the untreated cuttings. Numerous roots developed from the swellings 15–16 days after planting. In untreated cuttings, root formation was 3–4 days later and the number of roots much fewer. Kondo (1948) also obtained very good results in treating the vine cuttings with growth regulators. Heteroauxin (300 ppm), NAA (25 and 50 ppm), 2,4-D and 2,4-Dichlorophenoxybutyric acid (1 and 5 ppm) were applied for 25 hours to the bases of cuttings. Good results were obtained with all the growth regulators. Similarly, Heymann-Herschberg (1949) obtained overall improvement in the cuttings of root-stocks Solanix × Rupestris 216-3, Chasselas × Berlandieri 41 B and Rupestris du lot grafted with the variety Dattier by the application of ortho-chlorophenoxyacetic acid and B-naphthoxyacetic acid at several concentrations. If the regulator was applied to the apex of the stock as well as the base, it induced the formation of strong callus tissue. The effect was better on outdoor cuttings and lanolin paste method was better than talc. The influence was also more marked with 41 B which was more difficult to root. Martinez-Zaporta (1949), working on some difficult-to-root grape varieties found the improvement in the quality of roots after treatment with several growth regulators (IAA, IBA and NAA). The vines used were 41 B de Millardet and 161-49 de Couderc.

Treccani (1950) used NAA with honey for rooting vine cuttings. The most effective treament was 10 ppm NAA with honey. The honey increased the effect of the chemical by the virtue of energy provided by its sugars. The honey also increased the resistance of cells to growth regulators by preventing the coagulation of the proteins. Aguirre *et al.* (1951) found that IAA at 25 mg per litre was more efficacious than potassium permanganate on 41-B de Millardet and 161-41 Couderc vines. On 100-Richter variety, NAA and IBA were more efficacious at 5 and 10 mg per litre. Mullner (1952) reported beneficial effect of Floregin and Hoechst Nr 2608 in rooting of cuttings of *Vitis sylvestris* which are normally difficult to root. Cosmo (1952), however, did not find any beneficial effect of growth regulators on rooting of grape cuttings.

Aguirre *et al.* (1953) treated cuttings of 41-B de Millardet with IAA at 15, 25 and 50 mg/l for 6 and 12 hours and found that 15 mg/l and 6 hours duration of dipping was the best. With 169-49- C best results were obtained with 15 mg/l of IBA, whereas with 110 R the best results were obtained with 25 mg/l of NAA. In both cases, 12 hours dip was most suitable. Toskie and Avramov (1952) tried four growth regulators and of these Rooton (American) and Roche 202 (Swiss) had

the best effects on the rooting of cuttings. Chasselas × Berlandieri 41-B, which is difficult to root, responded most favourably to the treatments. Dragas and Avramov (1953) tested the effect of growth regulators on the rooting of grape cuttings of ten materials at 2 or 3 concentrations for each. Chasselas × Berlandieri 41-B stood first, Berlandieri × Riparai Kober 5 BB second and Berlandieri × Riparia Teleky third in order of their response to growth regulators. The effectiveness of heteroauxin (IAA) and potassium permanganate was also noted by Markin (1953). The treatments were, however, effective when applied in conjunction with the two methods used to induce rooting, i.e., 'kilijcevanie' and scratching the bases of cuttings longitudinally with a special instrument. The cuttings of variety Couderc 161-49 showed no significant increase in the rooting percentage after treatment with Rootone (5). The vigour of both the roots and shoots was, however, improved by the treatment. Rodriguez (1957), however, obtained an overall improvement in the cuttings of vine varieties 41-B, 99-R and 161-49 when treated with IAA or NAA. The best results were obtained with 24 hours immersion of the bases in aqueous NAA at 150 ppm followed by planting in fine sand under glass at 85–95 per cent relative humidity and 17°C temperature.

Bhattacharya (1959) found that for hard wood cuttings of Anab-e-Shahi grape (in leaf mould, 75 ppm IAA gave best results followed by 100 ppm IAA (in soil). A mixture of IAA (75 ppm) plus IBA (25 ppm) also proved better than either of the two at various concentrations (50 and 100 ppm) when Anab-e-Shahi grape cuttings were planted in soil. For Bhokri and Black Prince grapes, IBA (75 ppm) gave the best results.

Loquat. The effect of the growth regulator treatments on the air layers of Golden Yellow loquat was studied by Singh and Sharma (1954). They obtained 20 per cent rooting in control, 100 per cent in NAA (3 per cent), 50 per cent in phenylacetic acid (1 per cent), 80 per cent in IAA (2 per cent), 90 per cent in IBA (3 per cent) and 40 per cent in 2,4-D (1 per cent). In Pale Yellow variety, NAA (10,000 to 30,000 ppm), IBA (20,000 to 30,000 ppm) and IAA (10,000 to 20,000 ppm) were found to be effective on air layers. NAA, however, proved to be the best (Jauhari and Jit, 1960).

Olive and fig. Cuttings of olive and fig were treated with heteroauxin by the solution and lanolin paste methods. The solution method was found to be superior. The addition of sugar to the solution of heteroauxin increased root formation in certain cases (Evenari and Kaonis, 1938). Experiments were also conducted at the university of California to determine the rate and degree of root and top regeneration in tip cuttings of four fig varieties, and their response to various concentrations of IBA (Crane and Mallack, 1952). The treatment resulted in injury to three of the varieties and increased regeneration in the fourth. The greater the natural potentialities a variety had for regeneration, the greater was the injury resulting from the application of IBA.

Mulberry. Inforzato (1950) obtained good rooting in mulberry cuttings (variety Catania) by the application of Seradix B (Nos. 2 and 3). A number of growth regulators were also used at Conegliano Experiment Station in mulberry propagation by cuttings (Moretti, 1954). Little effect was noted in one variety. With the other, the best results were obtained by Roche 202 (1,000 ppm) and IAA plus NAA each at 50 ppm. Also forcing 1- and 2-year-old cuttings as 25°–28°C and applying IAA at 100 ppm to the base with or without the application of 50 ppm IAA to the apex gave the best results (21 per cent).

Breadfruit. Muznik (1940), working on the branch cuttings of tropical breadfruit in South Africa, obtained 80 per cent success after dipping in IBA (1 per cent) solution.

Jack fruit. In marcotting tests on jack fruit (Singh, 1954) IBA (1 per cent) markedly stimulated rooting. Darken brown shoots, 2–2½-year-old, gave better results than the younger ones.

Papaya. Sen Gupta and Chattopadhya (1954) treated shoots of papaya, 10 cm long, taken from the apex with IBA and NAA in lanolin. Cent per cent rooting was obtained with 3–5 per cent IBA, whilet here was no response to the NAA treatments.

Propagation by Grafts. Growth substances have only a limited application in the propagation methods by grafting. The reported beneficial effects in a few cases are the quicker healing of wound due to rapid callus formation and better stock and scion union in certain cases. Adverse effects of auxin treatment in grafting have also been noticed in certain cases. Kordes (1938) has reported that the immersion of stocks and scions of grapes for 16 hours in 0.01 per cent IBA solution and storing the grafts in moist sawdust before planting in the field increased root formation in the stock and the rate of callusing of the graft union.

Propagation by Seeds. Haas and Brusca (1954) has reported beneficial results of treating seeds of sweet orange with 2,4-D. He applied the growth substances by sprinkling the seedbeds with tapwater containing 0.0075 of 2,4-D. The response was almost a 100 per cent in stand and more vigorous seedlings.

Veldestra (1943) has reported an increase in percentage germination and bigger yields after treating the seeds of tomato with IBA. Choudhary and Singh (1960) reported that tomato seeds when soaked with proper concentrations of NOA, 2,4-D, CIPA and GA for 24 hours, resulted in better germination, quicker growth and higher crop yield. NOA (25 and 50 ppm), GA (5, 10, 15 and 20 ppm) and CIPA (10 and 20 ppm) gave significantly higher growth of the main stem and yield of fruit than control. 2,4-D (1 and 2 ppm), though gave better growth, it did not give higher yield of fruits.

The beneficial effects of plant regulators on tomato seed have also been reported by Handaw (1940) using IAA. Similar results have been obtained by Amlong and Naundrof (1937) with radish and also by Sebanek (1955) with pepper.

GA has been shown to substitute completely or partially for after-ripening in promoting germination in the seeds of peach (Donoho and Walker, 1957), sweet cherry (Fogle and McCrory, 1960), and hazel and beech (Frankland, 1961).

Poor germination in grape seeds coupled with a slow growth of the hybrid seedlings handicap the grape breeder in early evaluation of hybrids. Muller-Stoll (1950) reported improvement in seed germination of vines by the applications of aqueous solutions of heteroauxin and IBA. The effect was, however, not lasting. Pre-sowing treatment of grape seeds with GA was tried by Randhawa and Negi (1964). The highest germination (75 per cent) was obtained when the seeds were stratified for 80 days and then soaked in 500 ppm GA before sowing. Pieri (1959) also obtained early response of seed treatment with GA on seedling growth, while Fillippenki (1960) failed to obtain any response.

Kulkarni and Deshpande (1964), studying the effect of 2,4-D on germination of coconut, concluded that treatment with 100 ppm of 2,4-D was best suited for coconut seed germination. Clarence *et al.* (1956) reported that IAA was found to be superior to NAA in increased germination of groundnut seeds.

CHAPTER II

EFFECT ON FLOWER INITIATION, FRUIT-SET, YIELD AND QUALITY

INTRODUCTION

Plant growth regulators play a very important role in flowering induction in many horticultural plants. The past work on flower initiation clearly shows that there is a definite correlation between the auxin content and flower initiation (Leopold, 1948 ; Nitsch, 1949 ; Teles Palhinha, 1952 ; Cooke, 1953 ; Bakhinzen and van De Sande, 1953). The production of these growth hormones corresponds to the photoperiod to which the plant is exposed. Bakhinzen (1953) concludes from his experiment that the optimal length of photoperiod corresponds to the optimum amount of flowering necessary for flowering and that flowering hormone is produced only in the dark. In both long-and short-day plants at the time of appearance of flower primordia, there was a decrease in the auxin content but lowering the auxin content by various methods did not bring about flower initiation under unfavourable photoperiods (Cooke, 1953). Vlitos and Mendt (1954), studying the role of auxins in flowering, found greater amount of IAA in plants grown under photo-inductive day lengths. All these results indicate that for flower initiation hormones are essential to be present in plant tissues and these are produced under favourable photoperiodic induction.

The plant growth regulators have been used in the induction of flowering as well as for the inhibition and delay of flower induction which ever is suitable in case of individual crops. The initiation of flowering in plants has been extensively studied in pine apple by van Overbeck (1946).

PRACTICAL APPLICATIONS OF PLANT GROWTH

Apple. In apple, Fritzsche (1950) noticed that the successful thinning carried out in 1950 with NAA had a marked effect on 1951 (off year) blossoming. Treated halves produced little to abundant blossoms depending on variety, while no flowers were observed on the untreated control halves.

Litchi. Schigeura (1948), studying the blossom-bud differentiation in litchi, noticed the effect of sodium naphthaleneacetate on blossoming. His studies revealed that in litchi the vegetative maturity of the stem terminals has a bearing on blossoming during the following spring and that sodium naphthaleneacetate sprayings, if done properly, cause the maturation of these stem terminals.

The use of growth regulators in the flowering of litchi was also studied by Nataka (1955). Sodium naphthaleneacetate (SNA) promoted flowering only when there was heavy rainfall during October–November and with adequate water available from December to February. The application of SNA did not result in increased floral initiation and yield during a year with dry fall months and on trees that had yielded heavily the previous year. Under these conditions, the nature of the action of SNA appears to be inhibition of vegetative growth which in turn is a requisite for floral initiation.

Pineapple. NAA, even in small quantities of 0.05 mg per plant was found capable of inducing flowers on a limited number of plants, while 0.25 and 0.5 mg per plant caused practically 100 per cent flowering (van Overbeek, 1946). Although 2,4-D has flower-inducing powers equal to NAA, fruit induced by 2,4-D shows a lower average weight compared to those induced by NAA. This may be attributed to the adverse effect of 2,4-D on the development of young leaves. In another experiment, 1 oz of either NAA or 2,4-D was found sufficient for inducing flowers in 113,000 plants. van Overbeek reported that Cabezone pineapple plants treated with 0.001 mg of NAA flowered in 6–8 weeks and produced a full-sized fruit six months after treatment. His growth regulator trials with Cabezona, Red Spanish and Smooth Cayenne showed that flower formation could be induced in any month. He even went up to the extent of predicting the size of future fruits before treatment is given and thus making crop control in pineapple practical and profitable.

Relation of hormones and flowering was again studied in pineapple by Groszmann (1950). In trials started in Queensland in 1947, 5 ppm NAA applied at 2 fluid ounces per plant in spring and early summer induced flowering and increased the fruit weight by 7–14 per cent. B-hydroxyethyl hydrazine was used by Gowing and Leeper (1955) for inducing flowering in pineapple. The chemical was applied in water by sprinkling on 20 one-year-old plants at each of the four concentrations in each test. The first two highest concentrations (0.06 and 0.12 per cent) resulted in the production of flower buds in 18 and 20 plants respectively, compared with 1 in the control, two months after the treatment in mid-May. The second two concentrations (0.12 and 0.23 per cent) resulted in the production of flower buds in 13 and 18 plants respectively, compared with none in the control, two months after treatment in mid-September.

The effect of gibberellins on flower induction in plants is remarkable. Wittwer (1957) could induce certain biennials to flower at temperature slightly above the known inductive temperatures by the use of gibberellin even though they normally require low temperature to flower. Long-day annuals were induced to flower in short-day condition by gibberellin treatment.

Thus, pineapple is the most sensitive plant to the action of these substances and application of NAA is most suitable in the initiation of flowers. Gowing (1956) gives a hypothesis that SNA acts by competitively lowering the effective native auxin level in the stem tip, that the time of appearance of the inflorescence can be controlled by amount and frequency of SNA applications (by the length of time effective native auxin is kept low) and that the number of flowers produced is conditioned by the rate of SNA application. It also mentions that earliness of flowering is directly related to the effectiveness of flower induction.

INHIBITION AND DELAY OF FLOWER INDUCTION

Plant growth regulators sometimes inhibit the blossoming in fruit trees. This action has been exploited to avoid flowering at a time when the environmental conditions are unfavourable. White and Kennard (1950) tried MH (1,000, 1,500, 2,000 and 3,000 ppm) on apple, grape, strawberry and blackberry in late spring to delay blossoming. Blossoming of apple and grape was not delayed, but in strawberry blossoming was stopped temporarily and resumed later indicating that earlier treatment might be useful. Blossoming of blackberry was delayed by 24–38 days in comparison with that of check plants. Marth (1952) noticed the effect of MH to retard flowering in Bartlett pear. To avoid frost damage, Kritskaja Kryukova (1953) used KNA which delayed the opening of buds in pome and stone fruits. The blossoming of apple and pear was delayed by 5–7 days and in apricot and peach by 9 days by the application of NAA. Gortych (1953) also used NAA in cherry, apricot and peach and the flowering was delayed by only 15 days. Similar results were obtained when 2,4-D at 10–400 ppm was applied to the soil around the Ruth Gerstadter plum variety.

GROWTH REGULATORS AND FLOWER INITIATION IN VEGETATIVE CROPS

Application of Beta methyl alpha naphthaleneacetic acid in spray form at 5 ppm and nitrate of soda solution at 1 oz per gallon prevents the fall of flowers of the lima beans in hot dry weather. In U.S.A., the yellow Jersey variety of sweet potato frequently fails to flower. To induce flower in this variety, Howell and Wittwer (1955) got very encouraging results by spray application of sodium salt of 2,4-D (100 to 500 ppm). The greatest number of flowers were produced with 100 ppm 2,4-D.

Gibberellin has also been used for induction of flowers in case of beans and tomato. Wittwer (1957) tried gibberellin on beans and Early Chatham tomato and in all cases the flowering was earlier. Wittwer (1957) further reported that gibberellin treatment could induce flowering without cold treatment in case of biennials which included carrots, collards, cabbage and kale. But gibberellins were found effective only where the plants had reached a size at which they would normally flower when exposed to cold.

FRUIT-SET

Poor fruit-set is a common problem confronted by the fruit grower. The abnormal weather conditions like late frosts, unexpected rainfall, hailstorms, etc., determine largely the natural fruit-set in tree fruits. To overcome such vicissitudes caused by the vagaries of weather conditions, growth regulators have come in as a handy tool. Gustafson's discovery in 1936 that fruits could be produced artificially by treating the flowers with synthetic auxins, by-passing the pollination, marked the beginning of a greater appreciation of the potentialities of auxins for encouraging fruit-set.

Auxin and Fruit-Set in Fruit Plants. That the key factor limiting the fruit-set lies in the presence of production of auxin at the time of fertilization and fruit development has been appreciated from early times. Gustafson (1939) explained that the auxin from the pollen grain and pollen tube might be responsible for the early stages of fruit growth. However, small amount of pollen necessary to pollinate a flower may not carry enough auxin to account for early fruit development. The growing pollen tube may secrete or induce synthesis of an enzyme which may liberate auxins from precursors present in the pistillate tissues (van Overbeek *et al.*, 1941 ; Muir, 1942). Recently, Lund (1956) confirmed this view and said that enzymatic production of IAA in the ovary probably from precursors such as tryptophan and indoleacetaldehyde was activated by pollination. Thus it seems that fertilization itself must provide the stimulus for an internal auxin production which is responsible for the rapid growth of the fruits.

Studies on the distribution of auxin in different parts of the young fruits show that the highest concentrations are invariably found in the developing seeds. In the strawberry, Nitsch (1950) found relatively high amounts of other extraceable free auxin in the achenes, in contrast to the fleshy receptacle which did not yield any free auxin. Luckwill (1954) has elegantly demonstrated this theory in apples and pears.

Besides auxins, there are other chemicals which have been found to be influencing the fruits-et. Swarbrick (1948) found that estrogens caused parthenocarpic fruit-set in tomato. Recent investigations by Wittwer and Murneek (1957) have pointed out the potentialities of GA in increasing fruit-set.

Plant regulator has, therefore, two functions in fruit-set. First, it provides the tissues of the ovary with the factor initiating fruit growth. Second, it acts as an inhibitor of those processes which cause abscission of the flower stalk. The great importance in synthetic auxin sprays, from the growers' point of view, lies in their use in supplementing normal pollination in the setting of fruits. Some interesting results have been obtained in fruit crops which are briefly summarised below.

Apples and pears. Stuivenberg (1943) conducted a series of experiments on apple and pear. He removed the ovaries in unopened frosted flowers and the hollow receptacle, from which the fruit is formed, was filled with lanolin containing various auxins especially NAA at 100 kg per g. In Precoce de Trevoux pear, such drastic treatment with NAA and its sodium salt induced considerable fruit-set. IAA was found to be inactive. A series of sprayings of aqueous solutions first to the flower, then 3 or 4 weeks later at the time of fruit-set and subsequently at 10 to 14 days intervals has been found to be effective in ensuring fruit-set in pome fruits (Osborne, 1949). The most effective compound was the sodium salt of α (2-napthoxy)-propionic acid applied at 100 ppm. Swarbrick (1945) reported that a mixture of auxins applied as a water spray to young apple fruits damaged by frost produced 100 per cent parthenocarpic fruits in Miller's seedlings, but was without effect on Cox's Orange Pippin.

In parts of California, where Bartlett pear normally set parthenocarpic fruits, a single spray of 100 ppm 2,4,5-TP, just before flower opening, resulted in 20 to 26 per cent increase in yield but in cooler climate, similar sprays gave inconsistant results. Further, wide varietal differences in pears, in respect of 2,4,5-TP sprays, has been reported by Griggs *et al.* (1951). Similar experiments with American Delicious and Winesap apples have given negative results (Batjer *et al.*, 1951). The most promising attempt in apple was that of Osborne and Wain (1951) who produced small parthenocarpic fruits by spraying emasculated blossoms with 100 ppm α-phenoxypropionic acid.

In a recent report by Luckwill (1959), more fruit-set was obtained in pear with GA alone than with GA mixed with 2-naphthoxypropionic acid, whereas no fruit-set was noted without sprays.

Stone Fruits. There is no reported evidence of auxin sprays in influencing fruit-set and parthenocarpy in these crops. Randhawa and Nair (1960) in their experiments at I.A.R.I., New Delhi, got negative results with NAA, CIPA and GA in the Alpha variety of plum.

Small fruits. Para-chlorophenoxyacetic acid (4-CPA) has been found to induce greater fruit-set in grapes and currants (Coombe, 1953, 1954 ; Jones, 1955 ; Weaver, 1956 ; Weaver *et al.*, 1957). These reports point out the replacement or girdling in grapes by the use of synthetic auxins. Recently, GA has come into prominence in viticulture and many reports (Weaver, 1958 ; Stewart *et al.*, 1958 ; Pieri, 1959 ; Krishnamurthi *et al.*, 1959 ; and Bukovac *et al.*, 1960) have proved beyond doubt the potentialities of GA in improving the yield. Application of GA gave excellent results in seedless grape varieties especially by increasing the fruits size considerably. Boughtty (1959) in a recent communication, reported that NOA, 2,4,5-TP and NAA alone or in various combinations induced increase in fruit-set in cranberries. In strawberry, Singh and Randhawa (1959) and Singh, Randhawa and Jain (1960) found increased set with GA and 4-CPA sprays. In *phalsa* (*Grewia asiatica*), sprays of 10 ppm GA markedly increased the fruit-set, while 2,4,5-T was effective only at 5 ppm (Randhawa *et al.*, 1959). Jauhari and Prasad (1963) suggested that 2,4,5-T may be used with advantage for better yield and quality of *phalsa* fruit.

Fig. Considerable success has been achieved by substituting plant regulator sprays for caprification. Of the numerous substances tested, IBA, NAA, 2,4,5-T and CPA proved effective in inducing early-maturing parthenocarpic figs (Crane and Blondeau, 1950).

Citrus Many plant growth regulators have been tried in citrus. Stewart and Klotz (1947) found no increase in fruit-set and fruit-size in Valencia by aqueous sprays of 2,4-D (Erickson, 1951). In a later communication Stewart (1952) reported that the sprays of 2,4-D (16 ppm) applied at flowering time to Valencia trees caused an increase in fruit-size, but did not improve fruit-set. However, Hield and Stewart (1956) found increased fruit-set and fruit-size in Washington Navel Orange by aqueous sprays of 8 ppm 2,4-D.

Soost (1958) suggested the possibility of increasing fruit-set in the Clementine mandarin with 1,000 ppm GA. Hield *et al.* (1958) observed that in Bearss lime, with GA 100 and 1,000 ppm the fruit-set recorded was 86 and 79 per cent, compared to 56 per cent in control. Fruit set was significantly improved in Eureka lemon by GA (1,000 ppm) and in Washington Navel by 250 and 1,000 ppm GA. Randhawa *et al.* (1959) reported improved fruit-set in sweet lime (*C. limettioides* Tanaka) by

10 ppm GA sprays. 2,4-D (10 and 15 ppm) and 2,4,5-T (10 to 15 ppm) also increased fruit-set but not as effectively as GA. The efficacy of GA in increasing fruit-set in Jaffa and Pineapple sweet oranges was also reported by Randhawa and Sharma (1962).

Pineapple. Van Overbeek (1946) reported that by supplying one-quarter of a mg of NAA, 100 per cent fruiting was obtained in pineapple. Field trials in Costa Rica by Perez (1949) showed that ripe fruit could be obtained within six months of treating pineapple plants with 0.0015 per cent 2,4-D. These experiments also suggest that well-grown pineapple can be induced to fruit in mid-August, 2½ to 5½ months earlier than normal by applying 10 ppm NAA to each crown in mid-January.

Mango. Venkataratnam (1949) observed that in mango an increase in fruit-set was observed when 20 to 30 bisexual flowers were retained per inflorescence and sprayed with 10 ppm NOA. The fruit development was also parthenocarpic.

Plant Growth Regulators and Fruit-setting in Vegetable Crops. The effect of plant growth regulators on fruit-setting in vegetable crops is given below.

Tomato. Hemphill (1949) used three different growth substances, namely naphthaleneacetic acid (NAA), B-naphthoxyacetic acid (NOA) and P-chlorophenoxyacetic acid (4-CPA) at different stages close to anthesis. With all the chemicals, pre-anthesis treatment of greenhouse tomatoes resulted in reduced fruit-set. Spraying four days after anthesis resulted in the greatest fruit-set. Dhawan (1952) used 4-CPA as blossom spray and alpha chlorophenoxypropionic acid (CPP) as entire plant spray on male sterile John Baer tomato plants which resulted in considerable fruit development but as soon as spraying was stopped fruit-setting also stopped. CPP, 4-CPA, 2,4-dichlorobenzoic acid, Beta-naphthoxypropionic acid and 2,4-D failed to increase the fruit-set on male sterile John Baer tomato plants. In California, 29 experiments were carried out in 11 countries and the chemicals used were NOA, 2,4-D and the sodium salts of 4-CPA. All proved effective in increasing fruit-set. Leopold (1952), on his studies with excised flowers of self sterile strain of John Baer tomato, has shown that maleic acid, glutathione and manganous sulphate each and collectively increase fruit-set. Of all the compounds known to promote fruit-set, only maleic acid will appreciably increase fruit-set in the presence of glutathione and manganous sulphate. In Tasmania, Raphael and Richard (1953) has shown that the fruit setting can be significantly increased by using NOA and a number of other commercial plant hormone preparations. Krishnamurthi and Subramanian (1955) used ammonium salt of 2,4-D (2 ppm) which increased the fruit set in the 3rd, 4th and 5th clusters of tomato by about 191 per cent. Emmert (1956) got a better set and larger tomatoes by using Beta NAA plus boron than by using the hormone alone. 4-CPA increased the fruit set but did not affect fruit size. Singh and Kacker (1952) reported that tomato fruits produced by plant regulator treatments were seedless but their size was considerably reduced. Chattopadhya (1956) studied two plant regulators, namely 2,4-D and TCP and found TCP to be more effective in increasing the total fruit set in the treatment of old flowers, while only newly opened flowers showed higher percentage of fruit set in 2,4-D. Randhawa (1951) reported that in tomato various hormones applied as sprays to flower clusters at three different stages of development failed to increase the total yield. However, application of 4-CPA (20 and 50 ppm) increased the early yield. Chhonkar and Singh (1959) found that the application of NAA to flowers resulted in greater fruit set in tomato. Gustafson (1960) observed an increase in the number of fruit set and total weight of fruit per cluster when flowers and buds of the first cluster of field grown plants were sprayed with GA.

Brinjal. Krishnamurthi (1954) opined that in brinjal the application of 2,4-D to flowers advanced fruit maturation up to nine days and more than doubled the fruit set. The most effective method was the application of paste but the simplest were the aqueous sprays at 2 ppm which gave 58 per cent fruit set (control 27 per cent) and advanced maturation by seven days.

Other vegetables. The application of six plant growth regulators and two pollen parents had no effect on *Cucumis melo* but an increase of about 22 per cent in set was achieved by the use of 4-CPA at the time of pollination (Whitaker and Pryor, 1946). Wittwer (1957) reported increased set in cucumber by the use of gibberellin. Murphy (1957) found an increased pod set in beans by the application of N-metatolyl phthalamic acid at half pound per acre or with 2,4,5-T at 100 ppm.

EFFECT OF PLANT GROWTH REGULATORS ON YIELD AND SIZE OF FRUIT

Fruits. Clark and Kerns (1942-43) obtained increased weight in pineapple fruits by using a higher concentration of NAA but lower concentration had no effect. Trials in Queensland in 1947 showed that by applying 5 ppm NAA at 2 fluid ounces per plant in spring increased fruit weight by 7-14 per cent in apple. Gardner (1950) found that application of 2,4-D at 25 and 50 ppm effectively reduced the drop in Pineapple oranges and thereby increase the yield compared to the controls. But, it had no effect on Valencia oranges. Weaver and Williams (1950) obtained large berries in grapes with a spray of 5 ppm 4-CPA. Trials in California in 1950 on Bartlett pear showed that significant increase in yield could be obtained by the aqueous sprays of 2,4,5-T and its alkanol amine salt at 100 ppm when applied at the pink bud stage. Stewart (1951) obtained reduction in fruit drop in Washington Navel and Valencia oranges with 8 ppm 2,4-D. The yield was also higher compared to control. Stewart *et al.* (1952) noticed a significant increase in size of Valencia oranges by spray application of 2,4-D and 2,4,5-T. Pickett (1952), working with Royal apricot, got an increase of 10 per cent in the fruit size by the application of 2,4,5-T during the thinning operation. Hield and Stewart (1956) used 2,4-D for Washington Navel oranges and there was considerable increase in the fruit set and size. Erickson (1956) found that spray of 8 ppm 2,4-D or the same concentration of butyl ester of 2,4,5-T had favourable effects on the size and yield of Eureka lemons. 2,4-D significantly increased the yield but only slightly affected the fruit growth and quality. 2,4,5-T increased fruit size and weight but delayed maturity. It also markedly reduced the total yield.

Vegetables. In Florida, Schrader (1943) tried a spray of 0.4 per cent aqueous solution of IBA on been, but it resulted in a significant decrease in the yield. In 1946 experiments in Columbia, blossom spray of 4-CPA on snapbeans resulted in higher yield. Other related and effective subtances were 2,4-D and orthochlorophenoxypropionic acid. A 10 per cent decrease in yield was recorded by Prince (1949) for each ½ pint 40 per cent 2,4-D applied to potato crop during flowering. Hemphill (1949) noticed that in tomato the spray of NA-20 ppm, NOA-50 ppm and CIPA-10 ppm, 4 days after anthesis, resulted in the highest yield. Wittwer (1949) applied a spray of 40 ppm BNOA acid and 10 ppm 4-CPA, along with mechanical vibration, to a spring and autumn crops in seven tomato varieties, but significant yield increase occurred only in the American variety. Julliet (1949) in France got 33 per cent higher yield in tomato by the use of BNOA (100-400 ppm). The treated fruits were superior in weight, size and quality as compared to controls. Randhawa (1951) recorded an increased yield in tomato by spraying flower clusters with 25 and 50 ppm of 4-CPA. Danish Export tomato sprayed with TIBA at the rate of 25 to 100 mg per litre gave 64 per cent higher yield and matured fruits 2—3 weeks earlier than control. Dhawan (1952) reported that CPP, in an entire plant spray of tomato, significantly reduced the early yield. Trials by Krishnamurthi (1954) indicated that the treatment of 2,4-D paste (0.0025 per cent) to brinjals caused an increase in the fruit set but the fruit size was decreased. But when 2,4-D was applied in talc form the yield was not increased. Podesva (1955) noted that soaking the seed of the mid-season cabbage variety Pourovo Dobrovodsle for 24 hours in a weak acid solution of 0.01 to 0.02 per cent heteroauxin at 3°–13°C gave a yield of 23–25 per cent more than controls. Treatment with the same concentration at 20°C retarded growth and reduced yield. Davison (1957) tested various chemicals in glass-house tomatoes, and reported increased yields with 4-CPA.

CHAPTER III

CONTROL OF PRE-HARVEST DROP

INTRODUCTION

Fruit drop is a serious problem and in some fruits has become a limiting factor for increasing fruit production. In fact, fruit trees normally produce abundant flowers and all these flowers normally do not set fruit. There is a balance struck by nature to prevent exhaustion of the trees by over-bearing. Thus early drop of flowers or fruits should be neither too light nor too severe, if a tree is to produce a regular crop of normal size and quality. The problem of drop does not end there, because more often the orchardist is confronted with successive waves of abnormal fruit shedding. Comprehensive studies in deciduous fruits, especially in apple, have revealed that there are critical periods, during which the fruit fall is appreciable. The causes of such hazards have been investigated and it is seen that, apart from abnormal weather conditions, late frost, drought and hot weather, there are intricate physiological processes, which lead to the drop of immature fruits.

The drop of fruits is said to be influenced by an abscission mechanism, which is controlled by a layer of cells in the pedicel of the fruits. The formation and development of this layer of cells is held under check by a series of physiological processes. Plant growth regulators have come in as a handy tool in regulating this mechanism and phenomenal developments have taken place to such a magnitude that aerial spraying of 2,4-D has been advocated in citrus orchards of California to reduce pre-harvest drop.

Although considerable work has been done on this subject and several reviews have already been written (Vyvyan, 1946a ; Audus, 1959 ; van Overbeek, 1952, 1959 ; Naidu, 1953), the exact causes of fruit drop are not yet fully known and doubts have been expressed on the control of 'June drop', especially with the use of plant growth regulators. An attempt is made here to ferret out the salient features of the investigations done so far on this topic.

WAVES OF FRUIT-DROP

The abscission of partially developed fruits, subsequent to bloom, is not ordinarily continuous but proceeds in more or less definite waves. The period elapsing from petal fall to the first wave and between successive waves and their intensity depends upon several factors like species of fruit, variety, occurrence of fertilization, position of flower, prevailing weather conditions, etc.

Apple. Two abscission periods are usually recognised one termed as 'first drop' beginning shortly after petal fall and continuing for 2 or 3 weeks, and the other the so-called 'June drop'. The 'June drop' begins a few days after the completion of the first drop and continues from 2 to 4 weeks. It should be kept in mind that the term 'June drop' is somewhat a misnomer, since the second wave of abscission begins in certain regions in May and is completed in June. In other regions, it begins in June and is completed in July. The time at which the abscission of partially developed fruits occurs is related to the number of ovules fertilized and stability of the embryos produced. If fertilization does not occur in any ovule, the flower usually abscises shortly after petal fall. Murneek (1933) distinguishes this wave from the one in which the receptacle is slightly enlarged, depending upon the fertilization of 1 or 2 or 3 ovules. It is certain that these two waves overlap.

In case of 'June drop' the dropped fruits are progressive larger. The number of fruits falling in the 'June drop' is usually inversely proportional to those which abscised shortly after the petal fall. Baldwin, Grimes Golden, and Rome Beauty are reported to show a light first drop, but the later drop is somewhat heavier. Other varieties like Stayman Winesap and Delicious are prone to heavy abscission shortly after bloom, while later abscission is usually light (Howlett, 1927).

The pre-harvest drop in apples occurs in greater intensities than the earlier drops. The premature formation of the abscission layer responsible for the normal shedding of ripe fruit, seems to be the possible reason in this case (Vyvyan, 1946a). The intensity, time and duration of the pre-harvest drop are influenced by a number of factors, cultural treatments and varietal and morphological characteristics (Vyvyan, 1946).

Vyvyan (1946) devised an index on the rate of dropping whereby an accurate estimate of the relative effects of hormone sprays under the various experimental conditions could be worked out. The most accurate measure of this standardized rate of dropping or dropping index is given as below :

$$Q = \frac{100\,(\text{loge } X_1 - \text{Loge } X_2)}{t_2 - t_1}$$

X_1 = Total number of fruits on the tree at the commencement of drop.

AFO-070

X_2 = Total number of fruits on the tree after the drop has ceased.

$t_2—t_1$ = The period of observation in days.

Pear. Two periods of abscission were observed at East Malling, England, in the varieties Doyenne du Comice, Conference and Pitmaston Duchess. A very heavy early drop of non-fertilized flowers occurred, followed after an interval of two weeks by a slight second drop of partially developed fruits.

Peach. In general, two main waves of abscission are observed in the peach, although the second may consist of several minor crests (Blake, 1926). The first drop begins immediately after full bloom and extends over a period of from 2-3 weeks. It involves flowers having aborted pistils, those of which have not been pollinated and fertilized and possibly a small percentage in which fertilization occurred but the zygote or embryo aborted. The later period affects partially developed fruits in which embryo and endosperm development has taken place and whose size increases as the season advances.

Plum. The abscission affects flowers which show no enlargement after full bloom and partially developed fruits showing a wide range in size. Dorsey (1919) reported that the plum has three waves of abscission, first one consists of flowers with aborted pistils, and second and third consist of partially developed fruits.

Cherry. Abscission in sour cherry is reported to occur in three distinct waves (Bradbury, 1929). The first wave affects those in which the ovules are shrivelled indicating either that no fertilization has occurred or that zygote aborted immediately. The second and third drops consist of partially developed fruits.

Mango. Mango is also subject to heavy and continued fruit drop. Wagle (1928) and Mukherjee (1949) reported heavy drops of hermaphrodite flowers and young fruits amounting to 99 per cent or more. In case of Langra and Dasehri varieties an ultimate retention of only 0.38 and 1.2 fruits per panicle was observed by Musahibud-Din and Dinsa (1946). Most of this fruit drop occurs after setting and can be attributed mainly to competition among young developing fruits. This early drop may be considered as 'essential and beneficial' as the tree cannot carry to maturity all the fruits it sets initially. But in 4-6 weeks after full bloom, the remaining fruits on the plant attain good size and further continued drop causes heavy financial losses to the mango growers. Even during the 'off' years, when the crop load is very light on the tree, this drop is no less serious.

Citrus. In sweet oranges, especially, there are early-, mid- and late-season varieties, which give year-round production of fruits in many areas. But all the varieties flower in March-April and the period of maturity ranges from seven to twelve months. During this period, there is a certain amount of continuous fruit drop. But there are pronounced periods, when the shedding is severe. They are (i) first month following full bloom, (ii) 'June drop' which usually begins with the onset of warm weather in May-June or early July, and (iii) pre-harvest drop when the fruit is about to mature.

ABSCISSION

The abscission of fruits occurs at the abscission layer located at the base of the organ. This zone often consists of cells whose walls are thin, completely or nearly lacking in lignin and suberin. Separation without cell division occurs in leaf abscission of certain species and in ethyleneinduced leaf abscission of other species (Gawadi and Avery, 1950). These indicate that cell division is not an essential precursor of separation, its function appears to be the abscission scars (Gawadi and Avery, 1950). Separation may result from the dissolution of one or more layers of cells or cell parts. Addicott (1954) observed three types of dissolution : (i) the middle lamella between two layers of cells, dissolves, the primary cell walls remaining intact, (ii) middle lemella and primary cell walls between two layers of cells dissolve, leaving at most the thin cellulosic walls over the protoplasts (Eames and Macdaniels, 1947), and (iii) entire cells of one or more layers dissolve (Addicott and Lynch, 1955). In case where no dissolution of cells occurs, physical stress seems to be the most probable cause.

Various types of abscission have been classified but differences lie rather in the degree of restriction of the cell wall changes to particular sites, than in the actual mechanism of separation of the cells. Barlow (1952) quotes following examples : (1) fruit fall in mango is due to softening of cells near the stalk in the same way as in the rest of fruit flesh, (2) in the walnut-hull softening occurs first at the sutures but later spreads throughout the tissues, (3) in leaf fall in some *Rubus* spp. a broad but well-demarcated region at the base of the leaf stalk disintegrates, (4) in many leaves and in the mature apple fruit stalk, although there is an 'abscission zone' several cells thick, differentiated early in the life of the organ, separation is confined to a single layer of cells, and (5) separation is restricted to a layer of cells provided immediately before hand by cell division as in the pedicel of the apple flower or young fruit.

Auxin and Abscission. Application of plant growth regulators has given varying response to the retardation of abscission of leaves, flower parts, young and mature fruits on many species (Batjer, 1954 ; Vyvyan, 1946b ; Wester and Marth, 1950). It was not until 1933 that it was suspected that auxins play a part in the phenomenon of organ abscission (Laibach, 1933). Formerly the part played by natural hormones in abscission phenomena was only suspected, but in the last few years a number of independent investigations have indicated that natural auxins are probably the main controlling factors in all organs. Concerning fruits, significant contributions have been made by Luckwill and his colleages at Long Ashton. Luckwill (1948) showed that fertilization itself provided stimulus for internal auxin production in apple, which is responsible for the rapid growth of the fruit. He discovered that such a release of auxin followed the union of nuclei and further located the source of this hormone in the endosperm surrounding the embryo. Since then, intensive studies employing paper chromatographic separation of extracts from various tissues of fruits and seeds have revealed a much more complicated situation. In the apple, it was found that at least four different auxins accumulate in the growing seeds. Three of these are acids and one is a neutral substance but none seems to be identical with IAA. Only one of these auxins is present in any quantity in fruit flesh and it has been suggested that it alone may be responsible for the control of growth in the apple fruit, while the concentration in the seed of another of them showed a close inverse correlation with the two early waves of fruit fall. Hence, it was thought that in apple, auxin might be the main controlling factor governing abscission (Luckwill, 1954).

In Black Currant, two acid auxins, one of which is probably IAA and the other a neutral auxin, are produced in the seed as it develops, presumably as a direct consequence of the rapid protein synthesis. The IAA may be the hormone controlling fruit growth, while the second unknown acid auxin might be responsible for abscission control (Wright, 1956. In strawberry, there is a similar accumulation of total free auxin as the young achenes grow, but seven different components have been demonstrated. IAA represents never more than half the total auxin potential and the separate functions of the various components are still a mystery (Nitsch, 1955).

The fluctuations in auxin content are clearly outlined by Luckwill (1952). In the first drop, virtual absence of auxin in the seed is noted after petal fall. If the embryo-sac is then examined microscopically, endosperm is found in free nuclear state and auxin first appears when the endosperm becomes cellular. This latter event marks the end of first drop. In the 'June drop' period, the auxin is depleted by the growing embryo. Then it rises again to a maximum value. It is the low auxin

during this period, when the embryo is growing rapidly, which appears to be the primary cause of 'June drop'. Sharp rise in auxin production follows the completion of embryo growth, which marks the end of 'June drop'. Pre-harvest drop seems to be associated with the degeneration and drying out of endosperm after the embryo growth and auxin content in the seed again starts to fall.

In many species and varieties, however, attempts to regulate abscission by the application of auxin-like growth regulators have been successful (Vyvyan, 1946 b ; Wester and Marth, 1950). The two aspects of these results are worthy of consideration. The action of auxin depends on the site of its application. Growth substances and nutrients are transported preferentially to regions where auxin is in relatively high concentration, e.g. meristems and young fruits (Emsweller and Stuart, 1948 ; Went, 1938). Hence augmenting the auxin supply distal to an abscission zone in a fruit or leaf or petiole should help to maintain the flow of nutrients to the organ and thus indirectly retard abscission. Conversely application of auxin proximal to abscission zone should accelerate the pre-abscission withdrawal of nutrients and thus indirecly accelerate abscission. Secondly there is a diversity of effects following application of growth regulators to various species. Such a diversity can be explained in view of the known differences among species and the complicated nature of auxin physiology. The way in which the controlling action of auxins is brought about has been discussed with different hypotheses below.

Possible Causes of Abscission. Possible causes of abscission are described below.

Hormone-ethylene balance. Gawadi and Avery (1950) proposed a theory of regulation of abscission which has been supported by Hall (1952). According to this theory, leaf abscission is regulated by the balance of hormone (auxin) and ethylene in the leaf. The greater part of our limited information on the physiology of ethylene has come out from studies of fruit ripening. Some fruits like lemon, orange and mango do not produce ethylene as they ripen and in fruits producing ethylene, its production either coincides with or follows the ripening (climacteric) rise in respiration depending on the species. Addicott and Lynch (1955) dismissed this theory because ethylene is probably not an endogenous regulator of leaf abscission. Rather ethylene may be an interesting type of abscission accelerant, produced by some fruits during or following ripening.

Auxins gradient theory. Abscission physiology shows that auxin has a dominant role in controlling the normal order intervals of leaf abscission (Wetmore and Jacobs, 1953) and is the principal endogenous regulator of abscission. This theory (Addicott and Lynch, 1955) proposes that onset and rate of abscission are regulated by the auxin gradient across the abscission zone. Abscission does not occur when the gradient becomes gentle or disappears and is accelerated when the gradient is steep (high) on the distal side and low on the proximal side of the abscission zone. Abscission occurs when the gradient becomes gentle or disappears and is accelerated when the gradient is reversed. Addicott and Lynch (1955) reported positive correlation between the rate of change of gradient and rate of abscission. This theory is supported by (a) the lowering of the auxin gradient across the abscission zone previous to the abscission, and (b) the acceleration of abscission by proximal application. Addicott and Lynch (1955) state that this theory provides explanation for the perplexing observation that applied auxin may fail to retard abscission and may even accelerate it. For example, applied auxin could accelerate abscission by lowering the effective distal concentration through competitive interaction with endogenous auxin if transported by raising the proximal concentration.

Audus (1959), on the contrary, is of the opinion that this theory is very difficult to translate into terms of known biochemical processes and further more is not supported by all the facts. It is the absolute concentration of auxin at abscission zone rather than the direction of an auxin concentration gradient across it, that determined whether leaf fall shall be inhibited or promoted.

Biochemical explanation. Auxin inhibits the enzymatic processes involved in the decomposition of the calcium pectate 'cement' holding together the cells in the abscission region (van Overbeek, 1952). Very little is known about these processes and nothing at all about the direct action of auxin upon them. But it seems possible that the activity of some of the enzymes concerned in the metabolism of other pectic materials, may be affected by synthetic auxins (Audus, 1959). Changes in pectic materials may play an integral part in extension-growth of cell walls. Auxins prevent abscission which results from changes in the calcium pectate of the middle lamella between the cells of the abscission zone. Such changes are presumably enzymatic and auxin may inhibit them directly. The direct evidence on action of auxin on cell wall matabolism is scanty and conflicting.

Gibberellin mechanism. Luckwill's work points to the fact that the seed produces a regulator which is an 'anti-drop' hormone, which he named as *Malus auxin 2.* However, van Overbeek (1959) puts forward an hypothesis that this anti-drop regulator is not an auxin but a gibberellin. If the properties of an antidrop regulator given by Luckwill (1954) are compared with those of gibberellic acid, similarities noted by van Overbeek (1959) are : (i) both promote extension growth of wheat coleoptile sections, but much less than IA, (ii) both excel in bringing about parthenocarpic fruit development in tomato, (iii) both are produced during certain stages of seed activity only and the chromatogram of GA on leaf base sections look very much like that inhibitor 1 and auxin 2 of apple leaf extract on wheat coleoptile sections (van Overbeek *et al.*, 1957), (iv) both are capable of preventing abscission of young fruits. If we assume that the 'June drop' is brought about by a drop in the production of the anti-drop regulator, and (b) that this regulator is a gibberellin van Overbeek (1959) argues that it becomes at once apparent why auxin induced fruit thinning expresses itself as an exaggerated 'June drop'. It is at present becoming clear that gibberellin-controlled processes are strikingly antagonized by auxin. Wallhood (quoted by van Overbeek, 1959) found that the natural drop of young cotton fruits could be stopped by the application of GA and much promoted by application of IAA. van Overbeek (1959) concludes that no longer we can think in terms of growth control by a single auxin.

USE OF PLANT REGULATORS IN CHECKING FRUIT-DROP

Apple. The pioneer work on the application of synthetic auxins to the prevention of fruit drop in commercial orchards was that of Gardner *et al.* (1939, 1940) who made a very comprehensive study of a wide variety of compounds and treatments on a number of apple varieties. Attention has been directed since then almost exclusively to preharvest drop. 'June drop' has been little studied partly because earlier studies on it by Gardner *et al.* (1939, 1940) were noten couraging.

June drop. Vyvyan (1949) pointed out that early thinning could be carried out with greater confidence and precision. In spite of early discouraging results, experiments were carried out on Cox's Orange Pippin at East Malling Research Station using 10 ppm NAA alone and in mixtures with routine lead arsenate and dispersible sulphur sprays (Vyvyan and Barlow, 1947, 1948). Considerable degree of control was obtained in two very different seasons. 2,4-D at 10 ppm gave no control by itself, but did not affect the control of NAA when mixed with it. Vyvyan and Trowell (1951) point out that very early sprays applied in the second week of May may actually increase the rate of dropping.

Effective compounds. In the variety King David, Gardner *et al.* (1939, 1940) found that the order of effectiveness was IAA, IBA and IPA. The compounds include the acid itself, its sodium, potassium, calcium, and ammonium salts. The salts appear to be as effective as the free acid, although it has been suggested that the action of the salts is rather transient than that of the acid (Batjer and Marth, 1941). Naphthoxy acids such as B-naphthoxyacetic acid and B (1-naphthoxy)-propionic acid also have a checking action which is not, however, as marked as NAA compounds (Batjer and Marth, 1941 ; Swarbrick, 1943). The response of phenoxy-acids especially 2,4-D is varying, according to variety. Stayman Winesap and Winesap have responded well (Moon *et al.*, 1948 ; Harley *et al.*, 1948), whereas negative results were obtained in Delicious, Golden Delicious and McIntosh (Harley *et al.*, 1946 ; Edgerton and Hoffman, 1948). English varieties Worcester Pearmain (Swarbrick, 1945) and Bramley Seedling (Vyvyan and Barlow, 1948 b) were also found to be insensitive. Recent compounds which show promise with even insensitive varieties like McIntosh are, 2,4,5-T (Hoffman and Edgerton, 1952) and L-(2,4,5-trichlorophenoxy)-propionic acid (Edgerton and Hoffman, 1951 ; Batjer *et al.* 1954). A survey has been made of the action of all the chlorinated phenoxyacetic acids on six of the main Amercian varieties (Marth *et al.*, 1955). Grimes Golden, which is unresponsive to 2,4-D and 2,4,5-T, was extremely sensitive to 2,4-D. Precisely opposite results were obtained with the variety York Imperial. This last variety was also insensitive to 3-CPA and 4-CPA which were very effective on Winesap, Northern Spy, Golden Delicious and Red Delicious. These results point out the wide array of response between the compounds and the varieties.

Concentrations. The standard strength found effective by most workers is 10 ppm. Gardner *et al.* (1940) used as low a concentration as 1 ppm. Concentrations higher than the standard strength may give rise to certain disadvantages such as too firm 'sticking' of the ripe fruit during plucking. More recently the concentration effect has been investigated by the defruited stalk abscission technique with NAA and 2,4-D in Cox's Orange Pippin (Barlow, 1950). Examination of the results of these experiments indicates that for each compound there is a definite threshold concentration below which no significant action is observed. For NAA, this threshold varies between 1 and 10 ppm, whereas for 2,4-D it seems to be of the order of 50 ppm.

Form of application. The auxins are usually applied to the tree in the form of water sprays. Batjer (1941) has recommended that the spraying of the trees should be from inside and outside. Treatment of large orchards by spraying from aeroplanes has been tried in America with success (Scamen, 1944). Dusts have been tried extensively and are recommended by some workers as being easier and quicker of application than sprays. Vyvyan (1946a) has summarized the relative efficiency of dusts and spraying and the latter is certainly at the moment the more suitable method.

The addition of spreading of wetting agents has been widely used in fruit drop sprays, as in the case of fruit setting sprays. To aid retention of chemical, oil at the rate of 1/8 to 1 per cent is normally used. Compatibilities with fungicides and insecticides have been studied. Such combined sprays might be used for early varieties or as suggested by Vyvyan with oil or lime sprays in England to control red spider. It is often noted that pest control sprays themselves promote fruit-drop. Complete compatibility with lead arsenate has been reported by Overholser *et al.* (1943) and Vyvyan and Barlow (1948a) and also with sulphur, by the latter authors. The auxins have been found to be completely compatible with organic insecticides like DDT (Thompson, 1952). In this connection the opinion of Audus (1959), that the entry of weak auxin acids into plant cells is favoured by acidic and greatly retarded by alkaline conditions, need to be kept in mind.

Time of application. Vyvyan (1946a) has thoroughly discussed the duration of hormone effect and the time of spray application. Obviously these two factors are related to the varietal response. There are reports that an appreciable reduction in fruit drop can be observed only a day after treatment and others have recorded no effect until a week. It can be safely stated that maximum effect is reached in about 5 to 6 days depending upon the weather conditions. Timing of the sprays has been rightly claimed to contribute largely on the success of control of abscission. Vyvyan (1946a) recommended that a close observation was needed to calculate as nearly as possible the date on which the drop is expected. Spraying should be done before that date. This method is particularly recommended in those varieties which tend to show sudden fruit-drop just before harvest. In the varieties which are prone to long dropping periods, repeated applications may prove useful. There are strong indications that the duration of the effectiveness of subsequent sprays is very much shorter than that of the first spray, a second one applied up to five days after the first giving protection for only an additional two days (Batjer and Marth, 1941). Repeated sprays can be avoided by using auxins which exert long period of effectiveness. 2,4,5-TP applied a fortnight before the expected commencement of pre-harvest drop at 20 ppm brought about an even greater reduction of that drop than either NAA applied when dropping commenced (Southwick *et al.*, 1953) or two sprays of NAA timed to give the best control with that compound (Edgerton and Hoffman, 1951). With the variety Delicious, Thompson (1951) found that one spray at 10 ppm of the same chemical caused the fruit to 'hold'

47 days before harvesting, while in the same variety 2,4-D was insensitive.

Weather conditions. The weather conditions, immediately after the spraying, and conditions over the period extending up to the harvest, are two important considerations. Warmer mid-day conditions after the spray, gave a good response than cooler days (Batjer, 1942). This better response is traced to a more rapid absorption of the auxin at a higher temperature, but very hot dry weather conditions will accelerate the evaporation. Rain immediately following sprays is the adverse factor and artificial rain experiments by Overholser *et al.* (1943) indicate that the first two hours following sprays treatment are critical.

Effect on fruit quality. There are recorded evidences of the effects of auxin sprays on fruit quality. Recent reports of direct acceleration of the ripening process and intensification of red skin colour caused by pre-harvest sprays, have been made (Smock *et al.*, 1952), 1954 ; White, 1953 ; Southwick *et al.*, 1953). In the variety 'McIntosh', 2,4,5-T exerts better control on drop than 2,4,5-TP or NAA but has very little effect on ripening (Hoffman and Edgerton, 1952).

Pear. Majority of pear varieties have shown consistently good response to auxin sprays in those concentrations as are effective for apples (Audus, 1959).

Stone fruit. Slight reductions in drop have been observed in plum, but these were not sufficiently marked to recommend spraying as an economic proposition, except perhaps in French prune where 2,4,5-T is particularly effective (Harris and Hansen, 1955). No favourable report has so far been made in peach.

In apricot, interesting results were obtained. The drop in the Stewart variety ranges up to 30 per cent, and in Tilton variety as much as 50 per cent. Crane (1956) succeeded in forestalling this fruit drop with 25 ppm 2,4,5-T sprays at the time pit hardening of the fruit begins. Five years of experimentation with 2,4,5-T in California has proved that the size of apricots can be increased as much as 40 per cent, that pre-harvest drop can be eliminated, and that a red blush can be induced on the fruit under certain conditions (Crane, 1956 ; Bradley and Crane, 1957).

In almonds, 2,4-D (10 and 20 ppm) applied when the hulls first show signs of splitting, delayed fruit drop in the variety Peerless' for as long as seven weeks after application with no apparent injury to tree or fruit (Serr and Forde, 1952).

Citrus. One of the early investigations in preventing shedding of citrus fruits was initiated by Stewart *et al.* (1947). These trials were conducted in the 'June drop' period and negative results were obtained with 2,4-D and 2,4,5-T. In a later paper (1947), they reported that application of 2,4-D delayed the 'June drop' in Washington Navel orange without increasing the final yield. Stewart and Parker (1948) and Frith (1950) observed that sprays of 2,4-D (7 ppm ; 4 to 64 ppm) applied in April or June were equally effective in reducing 'June drop' in grapefruit and Washington Navel oranges. Zaini (1950) also recorded reduced fruit drop up to 55-60 per cent in mandarin. Randhawa *et al.* (1961) found that plant regulator treatments were least effective in arresting 'June drop', in Jaffa, Pineapple and Mosambi varieties of sweet orange.

Sweet orange. Jones (1951) found no effect of NAA on the drop of Washington Navel oranges. Stewart *et al.* (1951) obtained complete control in the same variety with 2,4-D. Halse (1952) also reported that 2,4-D was much more effective than NAA and successfully combined 2,4-D spray of 8 to 10 ppm with a copper fungicide. Frith (1950) reported a reduction in fruit drop in Washington Navel orange by a mixture of 2,4-D with a white oil Bordeaux Mixture used for control of red scale and black spot. Similarly, Stewart *et al.* (1951) and Erickson (1951) indicated that 2,4-D was compatible and effective when applied in combination with zinc. Davison (1952) reported that 2,4-D and 2,4,5-T at 20 ppm gave a 60 to 80 per cent reduction in drop. A single application of 2,4-D in late autumn before or after fruit drop had begun, reduced the loss for periods up to 15 weeks (Davison and Cederman, 1951 ; Erickson, 1951). A reduction in drop in Washington Navel orange has also been observed by Eteneau and Praloran (1954) and Iwasaki (1956).

In Valencia Late, negative results were obtained with 2,4-D and 2,4,5-T in controlling the pre-harvest drop (Reece and Hormic, 1952 ; Iwasaki, 1956). 2,4,5-T and 2,4-D were equally effective in reducing the fruit drop with no apparent injury to mature leaves. In the variety Pineapple, Sites (1954) found that 2-methyl 4-chlorophenoxyacetic acid, 2-methylphenoxy alphabutyric acid and 2-methyl 4-bromophenoxyacetic acid did not reduce the drop. Sodium salt of 2,4-D, diethanolamine salt of 2,4-D and triethanolamine salt of 2,4,5-TP at 25 ppm significantly reduced pre-harvest drop in Pineapple oranges (Reece and Hormic, 1952). In other varieties also, auxin sprays have been found to be effective (Davison and Cederman, 1951 ; Stewart, 1952). Investigations done at I.A.R.I. reveal that 2,4,5-T (30 ppm) was effective in Jaffa and Mosambi varieties and in Pineapple variety 2,4-D (15 ppm) was effective (Randhawa *et al.*, 1961), when the sprays were done in October. In a later experiment, sprays done at full bloom stage were studied and no effect was noted in respect of June and pre-harvest drops in the same three varieties. Only GA at 50 ppm in Jaffa and at 75 ppm in Pineapple was effective in significantly reducing the 'June drop' (Randhawa and Sharma, 1962). In another experiment, where the fruits of Jaffa variety were given two dippings in plant regulator solutions, one in the last week of October and again two weeks after, the pre-harvest drop was significantly reduced in 500 ppm 2,4-D solution followed in order by 50 ppm 2,4,5 T and 100 ppm 2,4-D (Randhawa *et al.*, 1961).

Other citrus fruits. Similar interesting results have been reported in other citrus fruits also. A significant reduction in fruit drop in lemons was obtained by 2,4-D and 2,4,5-T (Stewart and Hield, 1950 ; Erickson, 1952). Similarly, in grapefruit, sodium and triethanolamine salt of 2,4-D (Nankivell, 1952 ; McAlpin and Merrett, 1949 ; Hield and Stewart, 1956) were found effective. In mandarins, NAA was found to be favourable (Cresimanco, 1951). Randhawa *et al.* (1959) found gibberellic acid, 2.4-D and 2,4,5-T affective in reducing fruit drop in the sweet lime (*Citrus limettioides* Tanaka).

Quality of fruits. It was noted that there was a delay in maturity of the fruits as shown by the persistence of green rind in fruits sprayed with 2,4-D (Stewart and Parker, 1947 ; Stewart and Klotz, 1947 ; Stewart and Parker, 1948 ; Stewart, 1952 ; Stewart *et al.*, 1952). Fruit quality analysis at harvest showed that there was no consistent difference in the percentage of total soluble solids between sprayed and non-sprayed fruits (Stewart and Klotz, 1947). But they found an increase in the percentage of rag, rind and a decrease in the percentage of juice. Frith (1950), however, did not observe any reduction in quality by the smaller concentrations of 2,4-D. Stewart and Parker (1947) noted an increase in the number of rudimentary seeds and specific gravity with 2,4-D treatments. Erickson (1952) showed a correlation between the concentration of MH in the spray and total soluble solids in the juice. Hield *et al.* (1958) observed that fruits treated with gibberellic acid had lower rind thickness, higher amount of acid and juice, as compared to control. No marked difference in fruit quality by plant regulator sprays was, however, noted in the investigations reported.

Mango. Gokhale and Kantkar (1951) observed that post setting drop in Alfonso mango could be checked to a considerable extent with 25 ppm of NAA or 2,4-D in water. Kennard and Winter (1956) sprayed Amini mangoes with 50 to 800 ppm of 2,4,5-TP and found that sprays three and six weeks after blossoming hastened fruit maturity, reduced fruit size and increased fruit drop. Singh *et al.* (1959) found that NAA at 30 and 40 ppm proved to be the best treatment for the control of fruit drop in Fajri variety, registering 22 per cent drop as compared to 52 per cent in the control. 2,4-D (10 ppm) was effective in lowering the drop to 28 per cent. Maximum improvement in fruit size occurred at 10 ppm of 2,4-D and 20 ppm of NAA. Trials at Saharanpur (Singh, 1960) showed that 15 ppm of NAA and 10 ppm of 2,4-D reduced the fruit shedding from 18.89 to 19.39 per cent and 18.00 to 20.79 per cent respectively in Dasehri. In Langra, only 15 ppm 2,4-D was helpful in checking the loss to the extent of 23.15 per cent over the control.

CHAPTER IV

FLOWER THINNING AND CONTROL OF BIENNIAL BEARING

INTRODUCTION

Many fruit trees produce such excessive number of flowers in one year that substaining large number of fruits exhaust the trees partially or completely. Therefore, the trees fail to form new flower buds for the subsequent crop. The trees thus become biennial in their bearing habit, producing excessive number of blossoms in one year ('on' year) and few or none the next year ('off' year). To alleviate the situation, growers have, in the past, followed thinning of flowers or young fruits by hand. This tedious and expensive practice has, however, many disadvantages. Hand-thinning represents a major item in the cost of production in many fruit sections. As a cheaper and more rapid method than hand-thinning, chemical-thinning during the bloom period has received considerable attention. Besides being expensive, hand-thinning must be completed approximately three weeks after bloom in biennial bearing apples, for the primordia are initiated approximately three weeks after petal fall in mature trees.

Another need for thinning is the reduction of heavy fruit crops to aid in effective insect and disease control and to increase fruit size and quality. When excessive numbers of fruits are set on a tree, it may become difficult to obtain complete coverage of the fruit and foliage with sprays and the fruits harvested are small in size and relatively poor in quality. Excessive set may also cause damage to the trees as the fruits enlarge and weigh, the branches hang down and some may actually break.

Thinning of the flowers is considered to be more effective than thinning of the fruits as it saves the food materials used in growth and development of fruits. But it is a much safer practice to thin after the natural drop is complete, otherwise the total thinning may be more than is actually desired. Very encouraging results have been achieved, at least with heavy-setting apple varieties, by chemical-thinning.

Auchter and Roberts (1935) were the first to demonstrate that chemical sprays could be used effectively to thin apple flowers. Consequently the toxic substances such as phenols and cresols were also used to kill off some of the blossoms. Burkholder and McCown (1941) were the first to find that an auxin such as NAA could be effectively used to thin flowers.

PHYSIOLOGICAL BASIS FOR BLOSSOM AND FRUIT-THINNING

The thinning of flowers and fruits by auxins appears to be a function of three physiological factors. These are (a) checking natural pollination, (b) abortion of young embryos, and (c) forcing abscission directly by alteration of the auxin gradient at the abscission zone.

Prevention of Natural Pollination. Evidence has accumulated to show that auxins may alter the germination and growth of pollen (Addicott, 1943 ; Luckwill, 1953). Flower-thinning materials, such as cresols and phenols, obtain their greatest effects through a toxic action on opened unset flowers (Shepard, 1939). For this reason, they are principally effective only until fruit set has taken place. An advantage of auxin, as a thinning agent, is that there are other physiological means by which auxin may act as well.

Abortion of Embryos. The capacity of auxins to cause the abortion of embryos in young fruits was first demonstrated by Swanson *et al.* (1949) in *Tradescantia* fruits. According to Murneek (1952), the abscissed fruits of apple contained aborted embryos, whereas the fruits remaining on the tree contained a large proportion of normal embryos. The endosperm showed the most conspicuous deterioration in the abscissed fruits. Murneck (1952) proposed that the thinning action was a consequence of the abortion of the endosperm or perhaps of the inhibition of normal embryo growth (Murneck and Teubner, 1953). The endosperm tissue is the principal source of auxin to the young apple fruit (Luckwill, 1948), and deprived of its auxin supply, the fruits are expected to abscise.

Direct Abscission Control. The two thinning mechanisms described above are each probably effective through interference with the auxin production in the flower or fruit. It is well known that abscission can be obtained either by lowering of the auxin supply distal to the abscission zone or by supplementing the auxin supply proximal to the abscission zone. Evidence has shown that a third thinning effect of auxin involves supplementing the proximal auxin supply. Hartman (1952) suggested that auxin application may thin olive fruits by altering the auxins gradient across the abscission zone. Auxins are ineffective for thinning of peach flowers in the absence of foliage. Approximately 2 or 3 weeks after bloom, when the foliage has developed on peech trees, auxin sprays can be effectively used to thin fruits. Struckmeyer and Roberts (1950) have proposed that auxins thin flowers by causing an excessive number of flowers to set fruit, resulting in such a competition for nutrients for growth between the young fruits that many of them are forced to abscise for lack of such nutrients.

CHEMICALS, THEIR CONCENTRATION AND TIME OF APPLICATION

The nature, concentration and timing of chemical spraying considerably influence the effectiveness. Very few experiments have been published, giving information on comparative effects of extensive ranges of concentration, but experiments using small concentration ranges indicate that the response is usually quantitative. The timing of auxin thinning sprays is much less crucial than the timing of caustic sprays. The caustic sprays may be applied effectively only during the blossom period and after some fruit set has occurred, whereas auxins sprays may be effective for four weeks after bloom.

Following the work of Murneek (1950), it was established that two types of compounds could be most commonly used ; (a) dinitro compounds (DNC) in liquid or powder form as flower thinning sprays, and (b) NAA for fruit thinning.

The tentative recommendation given by him was the use of NAA at 20 ppm. Fisher (1953) obtained effective results on chemical thinning of apricots with the use of dinitro compounds. Abbott (1954) strongly recommended the use of NAA for thinning different fruits.

In a comparison of low volume and normal powder spraying with DNC for blossom thinning of apples. Houter (1952) got good results with both the methods, but recommended the use of higher concentrations with the low volume machines in apple. Thompson (1954) obtained encouraging results with 25 to 60 ppm of naphthalenacetamide in Jonathan and Stayman apples.

The relationship between spray concentrations and thinning effect was found to be approximately logarithmic by Abbott (1954), by use of NAA sprays at 2,5,10,25,50 and 100 ppm at 8 or 9 days after petal fall on Early Victoria, Lave's Prince Albert and Laxton's Superb apples. Hoffman (1954) recommended the use of a product containing naphthaleneacetamide for commercial use as an apple thinning agent. The amide was closely related to NAA but his trials showed that it was a milder thinning agent and softer to use under many conditions. Tenenhaum (1954) noted the beneficial effect of α-NAA at 20 ppm on Gravestein and Reive des Reinettes apple trees just after full bloom. From results of trials carried out during 1951-54, Hoffman, Edgerton and Fisher concluded that the amide was more moderate in its thinning effect than the acid, in spite of the fact that it was required in higher concentration. Wurgler and Aubert (1955) applied 5 g NAA in 100 litres on Golden Delicious trees and obtained better results compared to 3 g/100 litres concentration. NAA was applied 10 days after petal fall.

According to Davison (1955), thinning sprays of DNC and NAA on Sturmer apple were most effective. Moreover, trials throughout New South Wales, published in 1955, had shown that a single spray of 10 ppm NAA, applied at petal fall, effectively thinned Delicious, Jonathan and Granny Smith apples. Richards (1956) recommended satisfactory use of MCPA and NAA for thinning twelve varieties of Tasmanian apples. Kasahara and Oguro (1956) observed that the use of 10 ppm NAA, one week after full bloom, gave very encouraging results on American Summer Pearmain and Jonathan apples. Harley *et al.* (1957) indicated that in frost-affected apple orchards in bloom, leaf absorption of NAA was highly increased. Hence, its concentration could be reduced. Southwich and Weeks (1957) presented data from 15-year-old apple trees and indicated that NAA amide was a safer and milder thinning material than NAA. NAA might be necessary on certain varieties subjected to excessive cross-pollination. According to Horsefall and Moore (1957), addition of a detergent (Tween 20) to NAA sprays enabled even the reduced concentration to be effective in thinning Golden Delicious, when applied 17–21 days after full bloom. Thinning of Halehaven peaches was also successful when applied 35–48 days after full bloom. Abbott (1957) applied aqueous sprays of 25 and 50 ppm of naphthaleneacetamide to branches of Miller's Seedling, Lord Lamhourne, Prince Albert and Laxton's Superb apple varieties 2–4 days after petal fall. All varieties gave encouraging results and Laxton's Superb and Miller's Seedling were the least, and Crawley Beauty and Lane's Prince Albert the most responded to this treatment. Fernquiet (1957) observed that sprays of NAA (20—30 ppm) were generally successful with Cox, but were less satisfactory with other apple varieties.

Verner and Del (1949) used Elgetol on peaches for thinning and noted some promising results over two years, but the results, particularly between different varieties, were too variable to make any specific recommendations possible He also mentioned the successful use of NAA sprays on Elberta peach in Missourie. Peach blossom thinning trials with Elgetol sprays (20 per cent sodium-di-nitro-ortho-cresol) gave very variable results. A relative humidity of 85 per cent or more with temperature below 19°C was found to be needed for satisfactory thinning. Kelley (1953) found application of growth substances most effective when applied two weeks after shuck fall. This drop was due to excessive 'June drop'. Ronzoni (1954) presented an account of experiments on the fruit-thinning of peaches by spraying with 24 per cent DNC at full bloom to kill the stigmas, followed by hand-thinning after 7–9 weeks. In the self-fertile mid-season varieties Gaillard 2 and Anna di Balducci, the treatments were successful. Again, Kelley (1954) noted from tests on Elberta and Halehaven peaches that the best time to apply thinning sprays was two weeks after shuck-off stage. NAA formulations seemed to be the safest spray material, whereas naphthyl acetamide was ineffective Lalatta (1957) observed that early fruit-thinning of S. Anna di Balducci peaches was strikingly more successful than late thinning in giving high quality fruit and improving production.

Harris and Smith (1957) presented the data indicating that the nut crops of the Moore pecan could be thinned effectively by spraying with MH, 2,4,5-T or 4-CPA. They also obtained encouraging results for thinning of Californian Olive orchards with NAA.

METHODS OF TREATMENT

Apple. Davidson *et al.* (1945) used sodium salt of NAA (0.002 per cent) at full bloom. The yield of Baldwin was reduced by 60 per cent. Flory and Moore (1947) and Kenworthy (1947) reported promising results from a complicated compound, when applied after the natural drop of the blossoms.

Blommaert (1954) reported significant results in Golden Delicious apple with NAA and NAA mide. NAA applied at 30–50 ppm, 1 to 2 weeks after full bloom, gave 39–45 per cent reduction in fruit set. NAA-mide also gave similar results.

Results of various investigations in this field are summarized below.

REDUCING FRUIT-SET IN WELL-KNOWN VARIETIES OF APPLES BY USE OF AUXINS

Variety	Compound employed	Investigators	Results
Newtown	NAAmide 40-50 ppm	Lilleland and Koch (1958)	Application at 70 per cent petal fall gave satisfactory results.
Golden Delicious	NAA+Tween 20 (a detergent)	Horsefall and Moore (1957) Harley and Moore (1957)	Application 17 to 21 days, after full bloom gave significant results.
Miller's Seedling, Crawley Beauty, Laxton's Superb	NAAmide 25-50 ppm	Abbott (1957)	Applied two to four days after petal fall; 40-60 per cent thinning.
McIntosh, Delicious and Northern Spy	NAA 10-20 ppm	Blair (1952)	Sprayed at or soon after the calyx stage gave significant results.
McIntosh, Delicious and Northern Spy	NAA 10 ppm	Mitchell (1952)	Applied after full bloom; good thinning was obtained.
Baldwin, Yellow transparent, Wealthy and Golden Delicious	NAA 20 ppm	"	"
Jonathan and Delicious .	NAA 10 ppm or DNC 0.2 to 0.4 per cent	Brough (1951)	Spraying at or just after full bloom gave promising results.

Several other investigators, like Struckmeyer (1951), Batjer (1952), Richards (1956), Southwick and Weeks (1952), etc., have suggested use of different chemicals, depending upon the age and vigour of a species or a variety of the fruits. Hoffman (1954) suggests the use of a product containing NAAmide commercially to thin apples.

Peach. Hibbard and Murneek (1950) suggested the use of NAA and NAAmide at 20 ppm 4 to 5 weeks after full bloom. Langer (1952) reported that the fruit of several peach varieties was reduced by maleic hydrazide (MH) at 500 ppm or above. Lalatta (1954)] recommends the use of DNO sprays (0.15 per cent sandolina) at 70 per cent bloom. Horsefall and Moore (1957) suggested addition of a detergent (Tween 20) to NAA spray, as it reduces the concentration required for effective thinning in Halehaven peach. In the self-sterile J.H. Hale peach variety, chemical thinning has proved to be unsatisfactory, and the best time for hand-thinning is after the 'June drop' (Ronzoni, 1954).

Pear. Anjou, Hardy and Winter Nelis varieties have been successfully thinned with 100 ppm 2-4 TP (DeTar *et al.*, 1950; Batjer and Uota, 1951).

Richards (1956) tried MCPA and NAA for thinning some pear varieties and found NAA to be more satisfactory.

Other Fruits. Some very interesting results have been obtained in thinning of olive (Hartmann, 1952). If NAA is applied to the flowers, too much thinning results, but resistance to the auxin builds up at the young fruits begin growth. Use of 125 mg/l NAA with a light oil in the spray had good thinning effect after the fruits had grown 3 to 5 mm in diameter.

Vrijhof and Oele (1951) suggested the use of 0.04 to 0.05 per cent DNC for the thinning of plums. Pecan set has been reduced to 30 to

50 per cent of the normal with 0.5 and 0.2 per cent Elgetol solutions applied in a compressed air sprayer (Dodge, 1944). Erickson and Richards (1955) advocated the use of 2,4-D (16-20 ppm) to reduce the fruit set in Valencia orange.

CONTROL OF BIENNIAL BEARING HABITS BY CHEMICAL SPRAYS

Many of our fruits of commercial value are prone to alternate bearing. Apart from apple, pear, peach and plum, other fruits like, mango and some citrus species are apt to bear alternately or irregularly. The most striking use of thinning sprays is in the control of biennial bearing.

Not much work has been reported regarding the use of chemical sprays in mango and citrus, but some interesting findings have been reported in apple and some other temperate fruits. Heavy bearing apple varieties such as Wealthy, York Imperial, Yellow Transparent and Golden Delicious, if adequately thinned in the 'on' year, give a full commercial crop in the succeeding 'off' years (Hoffman and Geluewe, 1943). One set of experiments is described by Batjer and Thompson (1948), in which DNO sprays were applied at full bloom. Murneek (1944) suggests the use of DNO sprays at 1–2 per cent. Hemphill (1954), however, reports good thinning without damage to the foliage from spraying with 25 to 60 ppm of Naphtheleneacetamide at the petal fall stage. Longley (1954) reports that biennial bearing habit was broken in the McIntosh apple by spraying with 25 ppm NAA three weeks after full bloom. Edgerton and Hoffman (1955) suggest that N-I naphthalenethalamic acid (NPA) may prove better than DNO sprays for peaches.

FACTORS AFFECTING THE SUCCESS OF CHEMICAL SPRAYS

Physiological Factors

Vigour of the tree. Large husky spurs are more resistant to thinning sprays than the small weaker spurs (Murneek, 1950). The limbs which are healthy and vigorous in growth are more resistant to these sprays, whereas trees or limbs weakened by disease, like fire blight or by insect damage, are more susceptible to thinning sprays (Leopold, 1955). Lower concentrations can, therefore, be effectively used on devitalized and unhealthy trees.

More vigorous plants generally set a larger proportion of fruit, so relatively higher concentrations of chemicals need to be used. More vigorous trees have also been found to be more resistant to leaf injury by auxin sprays (Leopold, 1955).

Nitrogen level. Nitrogen level also influences abscission and thinning. Plants relatively rich in nitrogen generally shed fewer fruits by natural drop, and are more difficult to thin with auxin (Burkholder's unpublished work ; cf. Leopold, 1955).

Age of the fruit at the time of spraying. Peaches become more susceptible to thinning sprays three weeks after full bloom, but apples become more resistant after two weeks. After the apple fruits have reached the age of 4 to 6 weeks, the large amount of natural abscission 'June drop' is completed and after that even high concentrations of auxins are ineffective (Southwick and Weeks, 1950). Hartmann (1952) found no significant effect of auxins, when used for thinning olives, after the natural drop had occurred. Batjer and Thompson (1948) reported that auxin applications selectively thin the fruits on week or small spurs.

The fruit thinning action of auxin sprays brings about an increased fruit size. Luckwill (1953) studied the relationship between the thinning action and fruit size with respect to the time of application of the spray. The most effective thinning and greatest fruit size in apple were obtained when the spray was applied at petal fall. Applications later than this caused rapid decline in fruit size.

Edgerton and Hoffman (1952) observed that thinning of fruits gave increased winter hardiness to trees in the succeeding winter season.

Environmental Factors

Temperature exerts a strong influence on the shedding of flowers and fruits naturally as well as in response to auxin sprays (Leopold, 1955). The flowers of many species of plants are shed at comparatively high temperatures. Lu and Roberts (1952) observed shedding of flowers in apple at 21°–24°C than at 13°–more 16°C. Too low (near freezing) temperatures also cause excessive drop of young apples. Temperature not only alter the need for auxin sprays, but effectiveness of spray treatment is also effected at the same time (Leopold, 1955).

EFFECT ON FRUIT-SET, YIELD AND QUALITY OF FRUIT

Every fruit grower is interested in yield and production of high quality fruits from his orchards. Blossoms and fruit thinning generally improved the yield and quality of fruits. Gardner *et al.* (1939) recorded the failure of petal fall sprays of NAA and amide to improve the set on several apple varieties, but made no mention of any decrease in set. To increase the set of Starking apples, Burkholder and McCown (1941) sprayed halves of trees during the bloom with NAA at 10 and 50 ppm and amide at 50 ppm. The two concentrations of NAA reduced the number of cluster setting fruits by 15 and 77 per cent respectively, while the amide at 50 ppm resulted in a reduction of 34 per cent. In studying the effect of growth regulators on the set of Starking apple, Greene (1943) used NAA sprays at 10, 50 and 100 ppm. The fruit set was reduced in all cases, with the greater reduction occurring at the higher concentrations. Abbott (1953) noted a reduction in fruit set in Miller's Seedling and Edward VII apple, when sprayed with NAA 8 days after petal fall. Lalatta (1954) reported that flower thinning with DNO sprays effectively reduced fruit set on S. Anna Balducci peach tree. Blommaert (1954) confirmed the reduction as 39 per cent and 45 per cent in Golden Delicious when sprayed with NAA at 30 to 50 ppm. In the later stages of apple embryo development, abortion or inhibition of the embryo could be secured without an accompanying abscission of apples (Teubner and Murneck, 1955). Synthetic growth regulators applied during early fruit development in apples could, among other effects, delay the abscission of the second drop which was otherwise unaffected by the treatment.

Many ornamental trees set fruits that are objectionable, because of the unsightly litter produced when they fall to the ground. Miller and Erskine (1949), working in Ohio, had experimented with NAA sprays for the purpose of defruiting Horse Chestnut, Catalpa, European ash, Honey locust and Eastern poplar. Results indicated that these trees could be effectively devoid of fruit set with NAA spray applied during the bloom period.

More recently, MH was found effective in blossom and fruit removal from peach tree when applied at 6,000 ppm in the early prepink stage (Batjer, 1954).

On the basis of studies made by Abbott (1954), the size of marketable crop was reduced in Early Victoria, Lane's Prince Albert rnd Laxton's Superb apple varieties when sprayed, with NAA at 2, 5, 10, 25, 50 and 200 ppm. He recommended the use of NAA as a postblossom thinning agent. Abbott (1954) further observed that fruit ripening was accelerated by 2,4,5-TP spray when applied to Pearman at 40 ppm at 6 and 7 weeks before the normal picking date. According to Ronzoni (1954), the application of 20 per cent DNO at full bloom in self-fertile Gaillard 2 and Anna di Balducci peaches greatly reduced the number of fruits and increased their size. The size of the fruit was improved in Gravestein and Reine apples by 20 ppm NAA sprays after full bloom (Tenemhaum, 1954). Longley (1954) reported increase in yield of several apple varieties by application of NAA at 25 ppm three weeks after full bloom. Davison (1955) noted increase in size of fruits in Jonathan when sprayed with DNC and NAA.

Higdon and Grim (1956) observed that undersized fruits at thinning time rarely become large by harvest time in Bartlett pear. Further, he reported one-third increased yield in large-sized fruits. Carbamate sprays had induced early fruit ripening in peaches as indicated by Horsefall and Moore (1957). According to Harris (1957), thinning between 60 to 90 fruits of Wight Cling peach produced same yield as when the fruits were not thinned. However, the quality of fruits from thinned trees was greatly improved. Thinning to 30 fruits per inch of butt circumference reduced both the total yield and the yield of canning quality fruit. Lalatta (1957) thinned the fruits of Durello and Rosa Mantonana apples with DNC and reported an increase in fruit size to an extent which practically compensated in total yield for reduction in number, improved fruit colour and gave satisfactory flower production in the following year. Uriu *et al.* (1958) indicated after a commercial-scale trial of naphthylacetamide at 40–50 ppm at 70 per cent petal fall, that there was significant increase in fruit size which ultimately increased profits.

CHAPTER V

HERBICIDAL ACTION OF PLANT GROWTH REGULATORS

INTRODUCTION

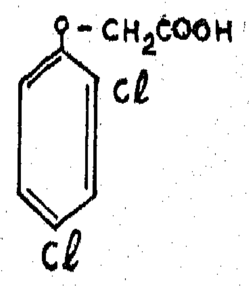
The idea of the use of auxins as herbicides was first given by Kraus of the U.S.A. and Slade *et al.* of England in 1940–41. They suggested that the growth regulators, which when present in plants in very minute quantities, accelerate the growth and may prove to be fatal to some plants when applied in higher concentrations. In 1945, they published their work with α-NAA, which when applied at the rate of 28 kg/ha to oats weedy with yellow charlock (*Brassica sinapis*) killed the later without injuring oats to any great extent. This seems to be the first instance in which an auxin was used as a selective weed killer.

This discovery resulted in an effort to search plant growth regulators more active than α-NAA. Simultaneous efforts of Slade *et al.* (1945) at Jealotts Hill Research Station in England and Zimmerman and Hitchcock (1942) in the U.S.A. revealed that substituted phenoxyacetic acids, namely 2,4-Dichlorophenoxyacetic acid (2,4-D) and 2-Methyl-4-chlorophenoxyacetic acid (MCPA) were important for their selective herbicidal activity. Field trials with these chemicals were first conducted in 1943-44 by Slade *et al.* in England and Hammer and Tukey (1954) in the U.S.A. Thereafter, numerous investigators started using these and similar compounds to determine their herbicidal effects.

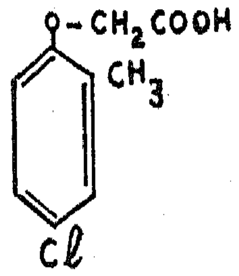
By substitution of various groups in phenol ring structure different phenoxy growth regulators have been obtained and screened for weed control, which can be classified as under :

1. Phenoxyacetic acids

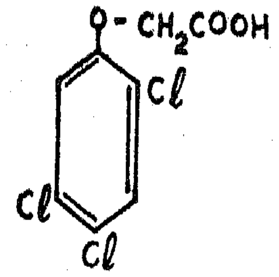
(i) 2,4-D (2,4-Dichlorophenoxyacetic acid)



(ii) MCPA (2-Methyl-4-chlorophenoxyacetic acid)



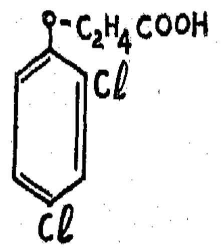
(iii) 2,4,5-T (2,4,5-Trichlorophenoxyacetic acid)



These three compounds are the original and still the most useful herbicides which have been adequately reviewed (Blackman *et al.*, 1951 ; Norman *et al.*, 1950). Agronomic studies in many parts of the world have demonstrated their usefulness for weed control in a number of crops.

2. Phenoxybutyric acids

(i) 4-(2,4-DB) (alpha 2,4-Dichlorophenoxybutyric acid)



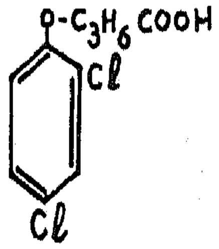
(ii) 4-(MCPB) (alpha 4-chloro-2 Methylphenoxybutyric acid)

(iii) 4-(2,4,5-TB) (alpha 2,4 5-Trichlorophenoxybutyric acid)

Work on these compounds has been reviewed by Muir and Hansch (1955). 4-(2,4-DB) and 4-(MCPB) possess a different type of selectivity which enables them to be used in legumes where acetic derivatives are toxic to these crops (Frayer and Evans, 1956).

3. Phenoxypropionic acids

(i) 2-(2,4-DP) (alpha 2,4-Dichlorophenoxypropionic acid)



(ii) 2-(2,4,5-TP) (alpha, 2,4,5-Trichlorophenoxypropionic acid)

(iii) 2-(MCPP) (alpha 4-chloro-2 Methyl-phenoxypropionic acid

Out of the many phenoxypropionic acids, only these are commercially used. MCPP kills many weeds that are resistant to MCPA or 2,4-D and is less toxic to cereals. 2,4,5-TP is as toxic as 2,4,5-T but is particularly less toxic to cotton (Zimmerman and Hitchcock, 1948).

4. Benzoic acids

2,3,6-TBA or (2,3,6-Trichlorobenzoic acid).

Out of the many benzoic acids, this is found to be the most useful. In monocots, it effects the nodal meristem often causing a weakness that results in lodging, while in dicots apical meristems are often completely inhibited and although the plant is incapable of growth, it does not die.

5. Others

In addition to the above-mentioned growth regulators, which are in common use as herbicides, there are many more which are under trial. A few of the most promising ones are: (i) Phenoxythioacetic acid, (ii) 4-Fluro and 4-Bromophenoxyacetic acids, and (iii) 2-6 phenoxyalkyl carboxylic acid.

PHYSIOLOGY OF HERBICIDAL ACTION OF AUXINS

Most of the work on this aspect has been done with 2,4-D and, therefore, results given below are mostly applicable to this auxin unless otherwise started.

Absorption, Translocation and Accumulation. Auxin herbicides, unlike other herbicides, must enter the plants and get translocated for bringing about death of the complete plant by altering its growth processes.

Beal (1944) stated that it is not known how or in what form the plant growth regulators that he used (substituted phenoxy compounds) entered the plant but Wood *et al.* (1947) stated that the plant growth regulators (radioactive 2-iodo-3-nitro benzoic acid) appeared to enter the plant in molecular form and are translocated as such. Weaver and De Rose (1946) showed that stomata did not appear to be important portals of entry of these compounds and that they are absorbed through the cuticle selectivity, the mechanism of which is not yet fully understood. On the other hand, Skoss (1955) found no movement of water-soluble 2,4-D through isolated cuticle devoid of stomata. He indicates that herbicides dissolved in aqueous carriers enter primarily through the stomata and only oils diffuse through the cuticle.

Passing through the cuticle these compounds enter the living cells—the mesophylls. The non-hormone herbicides kill these mesophyll cells but the hormone type compounds pass through the mesophylls and are released into the phloem vessels for translocation to the distant parts including the roots (Crafts, 1953). It is this feature of the auxins, like 2,4-D, which enables them to produce an effect on deep roots (Bakke 1944). There is a growing evidence that 2,4-D and possibly other plant regulators travel from leaves towards other parts of the plants in close association with the leaf synthesized food material—the carbohydrates—in the assimilate streams which is confined probably to the phloem (Barrons and Grigsby, 1945; Crafts, 1953; Weaver and De Rose, 1946). Finally, they get accumulated in regions of utilization in toxic amounts.

These compounds are not only absorbed and translocated through the leaves but they also enter the roots and are pumped in along the translocation stream through the non-living cells, the xylem vessels, to the various parts of shoots where again they accumulate and bring about injury or death of the plant (Henderson *et al.*, 1954).

Possible Mechanisms of Toxication. These are described below.

Histological changes. Swanson (1945) stated that meristematic tissues and those capable of reverting to the meristematic state are most readily affected by 2,4-D and that the effect of the compound is systematic in nature. Accordingly, cambium and phloem parenchyma are very sensitive tissues. Tukey *et al.* (1945), working with beans, found that 2,4-D in herbicidal concentrations increased cell division, enlargement and proliferation of cambium and phloem region around the xylem vessels which caused dislocation of food channels. The translocation of food is thus checked which possibly results in death of the plant.

Respiration. Associated with increased cell division following appli-

GOA UNIVERSITY LIBRARY
TALEIGAO - GOA
Donation ACC No. 070
Name of Donour L.B. Afonso.

cation of 2,4-D, is an increase in respiration rate which results in increased consumption of carbohydrates (Brown, 1946 ; Mitchell and Brown, 1945 ; Rasmussen, 1947 ; Smith *et al.*, 1947). It is not, however, yet clear whether auxins act directly on respiratory mechanism or via its effect on growth. There is a view that it is an indirect result of stimulation of some energy requiring process (French and Beevers, 1953). However, the relationship between 2,4-D action and increased rate of respiration is well established (Skoss, 1955). According to Taylor (1946) exhaustion of plant by increased rate of respiration may not be the only reason for such a high herbicidal effect

Photosynthesis. 2,4-D, when applied to soil or leaves (Bradbury and Ennes, 1952), causes the stomata of many plants to close down and the effect is proportional to the dose applied. Maciigewska (cf. Tukey, 1950) believes the closure of stomata to be associated with a decrease in phosphorylase and amylase enzymes of the stomatal cells due to a reduction in carbohydrate content. Working with radioactive carbon dioxide ($C^{14}O_2$), Freeland (1950) found that 2,4-D inhibits CO_2 assimilation or photosynthesis. Depletion of chlorophylls accompanied by chlorosis has also been reported (Mitchell and Brown, 1945). As amino acids formation in leaves is connected with photosynthesis, the former must also be affected. The result of all this is a breakdown of plant food manufacture. Contrary to this, Smith *et al.* (1947) working with potato showed that 2,4-D caused no reduction in sugar content of tubers. According to him, adequate proof that 2,4-D does act on respiratory mechanism is still lacking.

Uptake of nutrients. Inhibition of mineral uptake following application of auxin herbicides has been reported. It may be a direct effect of 2,4-D on nutrient absorption or in indirect effect by way of checked growth. However, in bean plants sprayed with 2,4-D absorbed much higher quantities of potash during first 8–10 hours which was followed after 24 hours by a marked decrease. This initial increase in nutrient uptake may be due to the initial increase in respiratory rate. That auxins may kill the plants by interference with potash metabolism has also been opined by Rhodes *et al.* (1950).

Production of toxic substances. van Overbeek *et al.* (1951) suggested that the herbicidal killings may be due to the production of toxic substances through abnormal metabolism induced by the presence of large amounts of auxins. Fults and Johanson (1950) found an increased content of scopoletin—a coumarin derivative which is toxic to plants. Hydrolysis of proteins and subsequent increase of fruit amino acids in plants, which may be toxic to plant tissues, have been observed by Sell *et al.* (1949). Skoog (1951) suggested an increased release of free native bound auxins by 2,4-D treatments, which may cause physiological and morphological disturbances.

Vitamins and enzymes. 2,4-D also effects vitamins content of plants. An increase in 'thiamin' and 'riboflavin' and decrease in 'carotene' content of kidney bean has been reported by Luecke *et al.* (1949). It is, however, unlikely that any of the recorded effect on enzymes alone could be responsible for the growth-regulating properties of the auxins.

Activation of phosphatase system. 2,4-D, after combining with suitable proteins may stimulate the liberation of inorganic phosphates from phosphorylated compounds with a subsequent release of energy greater in quantity than that produced by natural auxins (Bonnder and Bandurski, 1952). Loustalot *et al.* (1953) who observed release of large amounts of inorganic phosphates in bean plants due to lethal action of 2,4-D support such views. The exaggerated energy release may hamper the auxidative process of synthesis which cannot compete with the available hydrogen acceptors are, therefore, gradually inhibited. This theory might explain why toxic action of 2,4-D is slow and why this compound increases respiration, starch hydrolysis and depletion of food reserves, while at the same time growth process is inhibited.

It is finally concluded that herbicidal action is a combination of several of these functions or other functions yet to be discovered and which may differ from one set of conditions to the other.

Formative Effects of Toxication. After the application of 2,4-D to plants, it may take from few hours to a few days when the formative effects become visible (Watson, 1948). Growth of the plant is arrested, the stem and leaves get twisted and contorted and stem thickens and often splits. The foliage changes in size, shape and colour. Formation of adventitious roots is common. Also the roots may be swollen and often they get split up and put to fungal and bacterial attack. Finally, the plant dies. The death of the underground parts will depend upon the degree of translocation of the herbicide concerned. These formative effects may be seen in relatively short time but the plant may not die until two or three weeks after the treatment (Hammer and Tukey, 1954 ; Mitchell and Brown, 1947).

Mode of Selection Action. One of the most important properties of auxin herbicides is their mode of selectivity. They have the capacity to injure or kill only certain species of plants leaving the others unharmed. This selective action of auxins does not depend only upon morphological differences in plant species, but a characteristic biological mechanism may also be evolved which is yet only partially understood.

It is obvious that auxin herbicides enter into the plant and get translocated before they can alter plant growth. Accordingly, the nature and thickness of the cuticle and the formulations of the chemicals (acids, salts, esters) may be the factors. The structure and chemistry of the plant cuticle in relation to the entry of auxins has been reviewed in detail by van Overbeek (1952). Cuticle which itself is oily in nature allows a much easier and quicker penetration of esters dissolved in oils than salt formulations. Roots, on the other hand, do not probably make such a distinction because of the absence of the cuticle on them (Crafts, 1953). This explains why although aerial portions of monocot crops like sugarcane are comparatively resistant to 2,4-D, their roots are very sensitive to it.

The absorption and translocation of radioactive 2,4-D was much slower in monocots than in dicots (Crafts, 1953). The authors postulated a block in intercellary meristems on monocot leaves. But anatomically such a block has not been demonstrated. Mitchell and Brown (1946) using been (dicot) and oats (monocot) plants concluded that the differences in sensitivity of these two types of plants could not be accounted for on the basis of differences in absorption, translocation or accumulation of growth regulators, since with equal concentration of these in the young leaves of bean and oats, the growth of the former was greatly reduced but that of the latter was not affected.

Biological resistance of various plant cells against different auxins has also been considered. Such protoplasmic resistance may be due to factors like the electrical charge of the protoplasm which determines whether a particle is attracted or repelled, the acidity of the sap (Hammer and Tukey, 1954), and the nature of the proteins in the protoplasm (Rasmussen, 1947) which vary to a considerable extent within plant species.

The selectivity of auxins against monocots and dicots may be accounted for on the basis that in dicots potential cambial layers are abundant and are generally in a ring like pattern close to the phloem cells (Struckmeyer, 1951). Presumably, proliferation of these weakly differentiated cells by auxins would destroy the phloem system and subsequently the translocation of food. In monocots, cambium being absent and the meristematic tissues being much less, no such disturbance occurs. But some species of monocots like bent grass (*Argrostis stolonifera*) are less resistant, because its stolons very frequently root at nodes making a dense shallow-rooted mat which affords ample meristematic parts to the action of these growth regulators.

However, irrespective of the mechanism of the selective action, studies indicate that in general when aerial portions of the plants are treated with auxins like 2,4-D members of the grass family are relatively little affected, whereas the so-called 'broad' leaf plant show varying degrees of susceptibility (Lee, 1952).

In variance with this generalization, IPC (Isopropyl-N-Phenyl carbamate) which is also a selective auxin herbicide, is toxic to grasses and comparatively unharmful to the broad-leaved plants.

Growth regulators like, 2, 4-DB and MCPB have still different types of selectivity. They are as such biologically inactive compounds. Their action depends on the presence or absence of certain (yet unknown) enzymes in the leaves of the plants, which convert them to the biologically active 2,4-D and MCPA respectively. Therefore, within dicots, they may be toxic to certain plant species and varieties and not to others (Muir and Hansch, 1955).

However, it should be emphasized that the selectivity is relative. The same chemical when used in low concentrations may not affect a particular plant, but when used in higher concentrations may injure or even kill it. Therefore, only when dosages, methods of application and crop species are properly co-ordinated, these compounds kill weeds selectively, without harming the crops (Lee, 1952).

APPLICATION OF PLANT GROWTH REGULATORS FOR CONTROL OF WEEDS

Lawns. Success of 2,4-D and MCPA, in lawns is based upon the fact that many of the common lawn grasses, including blue grass (*Poa pretensis*), dub grass (*Cynodon dactylon*) and rye grass (*Lolium perenne*) are resistant to them, whereas, many weeds occurring in lawns such as *Amarantus* spp. ; *Digera arvensis* ; *Taraxacum officinalis* ; various plantations and thistles ; *Convolvulus arvensis* and *Cyperus rotundus* are easily killed by them. However, some species of lawn grasses like bent grass (*Argrostis stolonifera*) are less resistant, in which case 2,4-D is not employed.

2,4-D or MCPA may be applied at the rate of 1.25 kg–1.7 kg per hectare as 0.1 per cent solution. Two or three applications, at monthly intervals, may be needed. Best results are obtained if these sprays are applied on clear days, when temperature is about 16°C. New lawns should not be treated until the grass is about 2.54 cm tall. Sprayings should be done with complete protection of flowers and shrubs as they are very sensitive to 2,4-D and MCPA even in very low concentrations. It is, therefore, safer to use these herbicides in off season when annuals are absent and perennials are generally dormant.

Vegetables. Apparently, in vegetables phenoxyacetic compounds cannot be used for weed control since these crops are too sensitive to this type of herbicide. However, 2,4-D, when properly applied, has been successfully used in potato and onion. Potato crop is adversely affected if spraying is done after the sprouting of tubers. Application of 2,4-D at the rate of 1.25 kg–2.25 kg per hectare 10 to 14 days after planting but before the sprouting of the tubers, has proved very satisfactory.

Recent discoveries of 2,4-DB and MCPB seem to be promising in controlling weeds in many other vegetables. Their success in certain varieties of peas has already been investigated.

Orchards. Control of weeds in orchards is limited to the contact herbicides. 2,4-D and related compounds should not be used at herbicidal concentrations, in the orchard. Flower and fruit trees are very sensitive to these concentrations. Grape vine is specially sensitive to 2,4-D and accordingly it should not be used in or near a vineyard. Strawberry plants are relatively resistant to 2,4-D at moderate application of 0.56 kg per hectare 2–3 weeks after the plants are set.

CHAPTER VI

ROLE IN PLANT BREEDING

INTRODUCTION

An important tool in the hands of the plant breeder is the induction of polyploidy, i.e., multiplying the chromosome sets of a group of cells. Due to the work of Blakeslee and Avery (1937) and Nebel and Ruttle (1938), it has been established that treatment with the colchicine, an alkaloid, is a simple and reliable means of doubling the chromosome number. Acenaphthene and Veratrine are reported to have similar effect (Gavandan *et al.*, 1938 ; Kostoff, 1933 ; Witkus and Berger, 1944). Any change in the chromosomes of an individual is passed on to the subsequent generations, and the alteration of the characters of the plant may be sufficient enough to make it a new variety. Polyploid plants are usually superior to the corresponding diploids in characters of horticultural value. They can further be used as parents for breeding certain desirable traits into the existing lines at the polyploid level. By crossing tetraploids and diploids, seedless triploid varieties may be obtained, as in case of water-melon. Colchicine treatment of haploid individuals which occasionally occur spontaneously, may induce diploidy and thus establish pure lines. Sterile hybrids can often be made fertile and pollen incompatibilities can be overcome. Cytological examination has revealed that many of our best varieties of cultivated species are natural polyploids. However, the use of induced polyploidy in plant breeding is relatively a new idea and as the potentialities are further exploited, fresh developments may be expected.

More recently, plant regulators have been found helpful in the plant breeding programme. In many varieties of plants, that are incapable of setting seed of fruit even on pollination, the use of growth regulators has increased both the number of successful crosses and the number of seeds per cross. Certain incompatibilities have been overcome and it has been possible to make some hitherto impossible distant crosses. Plant regulators might as well prove helpful by preventing flower and fruit drop and by inducing male sterility in certain plants. Rooting of callus shoots after treatment with certain plant regulators may be employed for inducing polyploidy also (Jorgensen, 1928 ; Lindstrom and Koos, 1931).

COLCHIPLOIDY

Treatment with Colchicine. Colchicine is effectively applied to actively growing regions where the cells are dividing rapidly. Its effect is highly specific and consists of inhibition of the spindle mechanism (Eigste, 1938 ; Nebel and Ruttle, 1938). Thus germinating seeds, buds or young growing stem tips are usually selected for treatment. The optimum concentration and duration varies with different species.

Establishment of Polyploid Races. In a treated region, all the cells do not become polyploid. Thus, the new shoots formed may show normal leaves interspersed along the stem with giant polyploid leaves. The shoots developing from the buds in the axils of the polyploid leaves will also be polyploid. New plants may be obtained from such a shoot by asexual propagation or by seeds if it produces flowers and seeds. In the latter case, the flowers must be self-pollinated or pollen from another polyploid plant must be used (Avery and Johnson, 1947).

Experimentally produced tetraploids are usually stockier plants than the corresponding diploids with thicker stem ; broader, thicker, darker, green leaves and larger flowers, fruits and seeds. The contents of various chemical substances may be greater in tetraploids for example, sugar content of beet (Peto and Boyes, 1940) and ascorbic acid content of cabbage leaves (Newcomer, 1943) and tomato (Sansome and Zilva, 1933, 1936).

The following is a list of some important horticultural plants in which chromosome doubling has been induced by colchicine treatment :

Apple (Dermen, 1952), avocado (Bringhurst, 1956), blackberry (Hull and Britton, 1958), cabbage (Barr and Newcomer, 1943 ; Karpechenko, 1937 ; Newcomer, 1941), cherry (Olden, 1954), cosmos (Newcomer, 1941), granberry (Dermen and Bain, 1941), cucumber (Shifriss, 1942), grape (Dermen, 1954 ; Olmo, 1952), guava (Janaki Ammal, 1951), lettuce (Thompsona nd Kosar, 1938), lily (Emsweller and Brierly, 1940), marigold (Emsweller and Ruttle, 1941), mulberry(Tozyo, 1954), papaya (Hofmeyr and Elden, 1942 ; Singh, 1953), peach (Darrow, 1949), petunia (Levan, 1939), pineapple (Kerns and Kollins, 1947), potato (Johnstone, 1939 ; Lamm, 1943), snapdragon (Emsweller and Ruttle, 1941), strawberry (Dermen and Darrow, 1938 ; Kluge, 1954), sugarbeet (Artschwager, 1942 ; Peto and Hill, 1942), tomato (Dereskericus, 1956 ; Newcomer, 1941 ; Shimamura, 1938) and watermelon (Hawthorne, 1944).

Induced Polyploidy in Plant Breeding. Some time to be added.

Breeding at the polyploid level. The polyploid plants may possess certain useful traits which can be combined with those of the existing lines by making crosses at the polyploid level. For example, wild scab-resistant species have been treated with colchicine to obtain tetraploids which may have crossed with susceptible tetraploid varieties of apple. Dermen and Darrow (1938) crossed the tetraploid obtained from *Fragaria vesca* with the octaploid garden strawberry and by backcrossing the sterile hexaploid thus produced with octaploid strawberries obtained some fertile 7-ploid and 10-ploid seedlings which preserved the desirable fragrance. Waldo and Darrow (1948) crossed the tetraploid Eldarodo with the octaploid native blackberry and produced hexaploids which are considered to be a new species of the mammoth type. Crane (1941) produced Merton thornless, a tetraploid blackberry which could be used for polyploid breeding. Tetraploids obtained from the diploid cranberry by Dermen and Bain (1944) were successfully crossed with the tetraploid *V. quadripetalum* and from these crosses improved cranberry varieties are being developed. Colchicine-induced tetraploids of the disease-resistant muscadines are being crossed with varieties of *V. labrusca* and *V. vinifera* to develop disease-resistant bunch type of grapes. Wild polyploids of delphinium have been crossed with cultivated polyploid strains to combine resistance with other desirable characters (Mehlquist *et al.*, 1943).

Overcoming incompatibilities. Stout and Chandler (1941) noticed that the change from a diploid condition to a tetraploid condition in *Petunia exillaris* was accompanied by a change from self-incompatibility to self-compatibility. Also pollen from the flowers of tetraploid branches could pollinate the flowers on diploid branches of the same plant but the reciprocal crosses failed (Stout and Chandler, 1941).

Production of triploids. Triploid varieties can be obtained by crossing tetraploids with diploids for inducing seedlessness, which is a desirable commercial character. A majority of the cultivated banana varieties and about one-fourth of the commercial varieties of apple are triploids (Sikka, 1958). Peto and Hill (1942) obtained triploid sugarbeets which were better yielding.

Restoration of fertility in sterile hybrids. The greatest use of induced polyploidy lies in the restoration of fertility in sterile hybrids. A hybrid which has received two unlike sets of chromosomes from its two unlike parents, becomes fertile on chromosome doubling, as each chromosome gets a partner to pair with at gametogenesis. The technique has proved useful in case of pineapples (Kerns and Kollins, 1947). Hexaploid cherries have been obtained by treating the germinating afterripened seeds of triploids from the crosses between tetraploid sour cherries and diploid sweet cherries with colchicine. Polyploidy has been induced in the sterile hybrids of *V. vinifera* and *V. rotundifolia* and the polyploids obtained may be used in the development of new root-stocks because of their increased vigour (Patel and Olmo, 1956). In attempts to obtain plums combining the hardiness of certain American species and the colour of Japanese plums, *Prunus spinosa* is being used as a bridge species in hybridization, using colchicine and N_2O for chromosome doubling (Olden, 1958). Colchicine treatment has improved the fertility of spineless hybrids from the cross between black currant and gooseberry (Rogers, 1954). Hull and Britton (1958) crossed the tetraploid Eldorado with the diploid raspberry Oregon 913 and obtained a vigorous and fertile hexaploid by colchicine treatment.

USE OF PLANT REGULATORS

Prevention of Flower and Fruit-Drop and Increase in Fruit-Set. For obtaining seed it is essential that the fruits should develop normally and persist on the plant till maturity. In some cases, flower and fruit drop is a great hindrance in the breeding programme. In cantaloupe breeding, only about 10 per cent of the crosses set fruit. Burrell and Whitaker (1939) increased the percentage of cantaloupe fruit set following hand-pollination by applying 3-indoleacetic acid (1 per cent) in lanolin to one lobe of the stigma just after pollination. They obtained 46 fruits from 78 treated flowers as against only 23 from 86 untreated ones. The increase in percentage of fruit set was attributed to a reduction in the drop of the pollinated flowers.

Excessive dropping of blossoms and small pods is a serious problem in Lima bean. Wester and Marth (1949) were able to reduce the loss by using a mixture containing 0.8 g IBA and 0.2 g 4-CIPA dissolved in 3 g warm glycerine and diluted with 96 g lanolin. The lanolin paste was pushed into scratches made on the base of the flower with a dissecting needle. The number of successful crosses was increased from 18.7 to 28.8 per cent and the number of seeds for pollination was doubled. The average number of seeds per pod was also increased from 1.95 to 2.43.

Overcoming Incompatibilities. Self and cross incompatibilities are fairly common in plants and are great handicaps in breeding (Stout, 1938). With the help of certain plant regulators, the difficulty has been overcome in some cases. For example, Golden Rose, a self sterile strain of *Petunia*, could be made self fertile by spraying the flowering plants with a solution of 10 ppm alpha-naphthaleneacetamide immediately before or shortly after self pollination. Obviously, the plant regulator neutralizes the effects of the ovarian secretion which diffuses into the style and inhibits or greatly retards the growth of the pollen tubes. This growth regulator has also been found to increase the self fertility or self compatibility of highly inbred and highly sterile strains of *Tagetes erecta* (African marigolds), cabbage and red clover.

Emsweller and Stuart (1948) used IBA, IAA, NAA, naphthaleneacetamide and 2,4,5-T in Easter lily (*Lilium longiflorum*). Dissolved in lanolin at concentrations of 0 to 1.0 per cent each chemical was applied on a wound at the base of the ovary, produced by breaking the petal where it was attached to the pistil, just at the time of pollination. Such a treatment of lily ovaries ensures success in some difficult crosses and overcomes some self incompatibilities. In all pollinations, naphthaleneacetamide (1 per cent) proved to be most effective. They have also shown that both the pollen and growth regulators contribute directly to fruit formation in lilies.

Miwa (1951) reported that self fertility in Hyuga natsu mandarin could be induced by NAA treatment.

Making Distant Crosses. At the John Innes Horticultural Institution, England, Crane and Marks (1952) obtained sexual hybrids between pear and apple for the first time. Actually they wanted to test the occurrence of apomixis in pears. They emasculated 16 flowers of a tree of the variety Fertility and brushed the ovaries with a solution of B-naphthoxyacetic acid (40 ppm). Four flowers were pollinated with the pollen of an un-named tetraploid variety of apple and 12 with the pollen of the diploid apple Crawley Beauty. After 24 hours, the ovaries were again treated with the growth regulator. Three fruits developed from pollination with the tetraploid apple and 12 from pollination with the diploid. Seed content and germination are given below :

Pear	Fertility 2X	Flowers	Fruit	Seeds	Seeds sown	Germinated	Survived
X	Apple 4 X	4	3	13	13	13	1
X	Apple 2 X	12	12	100	79	56	10

During the early stages of growth, the seedlings were very uniform and appeared to be pears of apomictic origin, but later unusual development showed that they were hybrids. Their hybridity was further confirmed after cytological examination by Brock (1954). The success of this technique depends upon the stimulation of pollen tube growth and the induction of parthenocarpy. Naturally parthenocarpic pear varieties are more favourable as female parents.

Induction of Pollen Sterility in Different Crops.

Grape. Iyer and Randhawa (1965, 1966) successfully induced male sterility in three varieties of *vinifera* grapes by using MH (500 ppm), TIBA (440 ppm) and FW 450 (0.30 per cent). In all cases, two applications of the chemicals were necessary to induce complete pollen sterility. In addition, FW-450 (0.30 per cent) prevented anthesis and anther dehiscence. Considering the fruit set and seed set obtained in the male sterile flowers, MH appeared to be the most promising. The chemical treatments did not influence seed germination.

Tomato. Rehm (1952) treated potted tomato plants, about a week before first flower ripening with Tri-idobenzoic acid (TIBA), 2,4-D, MH and NAA. Sterility for about eight weeks was obtained with 25, 50 and 100 ppm TIBA and 1 0, 25 and 50 ppm 2,4-D, whereas 50 ppm NAA and 500 ppm MH induced sterility for only 10 to 14 days. Moore (1958) used FW-450 (0.02 to 1.2 per cent) on several tomato varieties. The concentrations of 0.075 and 0.15 per cent induced pollen sterility for 10 to 13 days without causing female sterility. Field trials were also conducted on eleven tomato varieties employing four concentrations (0.075, 0.15, 0.3 and 0.6 per cent) of FW-450 sprayed thrice. FW-450 (0.075 per cent) failed to produce any appreciable male or female sterility but at 0.15 per cent this chemical produced fairly high male sterility for 13 days but pollen was never completely absent and a slight reduction in female sterility was also observed. At 0.3 per cent FW-450 caused a complete absence of pollen for 12 days during which time 30 per cent of the flowers pollinated with normal pollen set fruits compared to 50 per cent in unsprayed checks. The highest concentration of FW-450 used (0.60 per cent) induced complete male sterility for 10 days along with very low fruit set, accompanied by large deformation of the leaves. Walkof (1958) used 0.05, 0.50 and 1.10 per cent of FW-450 on tomato plants and noted that 0.05 per cent concentration sprayed twice, two weeks apart, had little visible effect. But one application of 0.5 per cent resulted in complete male sterility accompanied by thickening of the blossoms and fleshy stamens. On pollinating with good pollen, 25 per cent of the flowers set fruits, but the fruits were mostly fasciated and contained only 2 to 3 per cent as many seeds as in controls. The highest concentration used (1.10 per cent) proved toxic.

Nayland (1959) used 0.3 and 0.6 per cent of FW-450 and applied them when the first flower buds were present followed by a second spray after a fortnight. About one month after first spray, the flowers were pollinated with pollen from untreated plants to determine the ovule fertility. With the lower concentration, the self-pollinated flowers set a

few fruits, as in controls, whereas with 0.6 per cent concentration no fruit set was obtained without hand-pollination. Hempbill (1959) tried different concentrations of FW-450 and noted that, whereas the lower concentrations failed to induce male sterility the higher concentrations caused chlorosis, malformation and stunting of plants. Walter (1959) also noticed that although considerable male sterility was produced by treatment with FW-450 at 0.25, . and 0.75 per cent in most cases it was accompanied by stigma and ovule damage. On the contrary work at the Rohm and Haas Research Farm (Anonymous, 1959) has shown that 0.125 per cent FW-450 gave 100 per cent pollen sterility for 13 days without much adverse effect on ovule fertility.

Chopra *et al.* (1960) observed that MH induced complete pollen sterility in tomato with 50 ppm sprayed twice or 100 ppm sprayed once or twice in treatments made before the opening of the fruit flower, without greatly impairing the seed set.

Onion. Chopra *et al.* (1960) obtained complete pollen sterility by injecting 10 ppm MH into the plants before the onset of meiosis in the oldest bud of the inflorescence.

Cucurbits. Rehm (1952) used three chemicals, namely, 2,4-D, TIBA and MH and obtained complete pollen sterility in water melon, for more than one week, with 10 ppm TIBA applied every week; 250 ppm of TIBA applied once and 5 ppm 2,4-D applied every week. The female flowers which opened in all the treatments during the period of male sterility were partially fertile and the best fruit set was obtained with 250 ppm TIBA. Wittwer and Hillyer (1954) observed that squash of 20°C and 16-hour otoperiod produced the usual number of pistillate flowers without a single staminate flower by MH 250 and 350 ppm sprays applied twice. Similar results were also obtained by them in *Cucumis pepo*. Nakamura (1954) could induce male sterility in egg plants by applying 10 ppm of amine salt of 2,4-D. Nakamura and Terabun (1955) noted that treatments with 50 and 100 ppm of amine salt of 2,4-D caused a decrease in the number of male flowers and an increase in the number of pistillate flowers in cucumber.

Hensz and Mohr (1960) observed a striking reduction in open staminate blossoms on water melon plants treated with 0.5 per cent FW-450. Treated plants produced only one functional staminate to pistillate blossom, as compared to the ratio of 15 : 1 on control plants.

Celery. Roble and Honma (1959) applied FW-450 at concentrations of 0.85, 1.0 and 1.15 per cent (6 cc/plant) and obtained complete male sterility in all the treatments with high ovule fertility. But in all cases, the treatments resulted in some injury, depending upon the concentration.

Brinjal. Choudhury and George (1962) observed that whole plant spray of NNA (50 ppm), MH (600 ppm) and 2,4-D (20 ppm) induced pollen sterility ranging from 90 to 100 per cent, 14 to 28 days after spraying, and lasted for 5 to 12 days, in two varieties of brinjal in the summer and winter seasons. They opined that repeated spraying of these plant regulators, at intervals of 5–7 days, could prove to be valuable means for making hybrid seed production in brinjal much economical.

Beets and turnips. Plants of beets and turnips were treated by Wit (1960) with FW-450 (0.2 to 0.9 per cent) a few days prior to flowering. In beet, the fruit set gave the impression that even at a high degree of male sterility, there may be little influence on female fertility. In turnips, perhaps because the treatments were given at a very late stage, there was little or no response.

Cantaloupe. Lippert and Hall (1961) applied aqueous solutions of FW-450 (0.2 to 0.7 per cent) in cantaloupes and observed that the number of flowers was reduced in proportion to the chemical concentrations, although all concentrations reduced equally the proportion of staminate to hermaphroditic flowers. The chemical failed to prevent the production of functional pollen or ovules but reduced corolla growth, flower opening, and fruit set. The authors doubted its value as an aid in the production of hybrid cantaloupe seeds.

Ornamental plants. Very little work has been reported in case of ornamental plants also. Moore (1950) reported complete male sterility in gladiola (*Gladiolus* sp.) and China aster (*Callistephus chinensis*) by application of 0.24 per cent MB. Putt (1959) observed that inbred lines treated with FW-450 at different concentrations showed little evidence of selective gametocidal action. Whereas the pollen production was inhibited, the ovules became non-functional to some degree and in most cases seed set was very poor.

CHAPTER VII

SPROUT INHIBITION IN SOME VEGETABLE CROPS

INTRODUCTION

Reducing storage losses in some vegetables like potato and onion is an important problem. Thousands of tons of potatoes, onions, turnips and beets are lost each year from sprouting in storage. If storage temperature could be maintained below 7°C, very little, if any, sprout growth will occur. But in usual practice in common storage houses and cellars and outdoor pits, it is impossible to maintain such temperatures throughout the storage season. Besides this, certain undesirable characters come up during the storage in the low temperatures, e.g., sweetening of tubers. This is undesirable from commercial point of view. To avoid this, tubers are stored at higher temperatures which, however, unfortunately results in rapid sprouting. The discovery that growth regulators can affect the dormancy of plants, even at relatively high temperatures, has attracted much attention and has led to important practical applications.

PREVENTION OF SPROUTING IN STORAGE

Potato. In 1936, Elmer observed reduced potato sprouting when the tubers were stored with apples. This inhibition, he believed, was due to ethylene gas given off by apples. Denny (1942, 1945) concluded that potatoes treated suitably with certain growth regulators would not sprout even under favourable environments. Guthrie (1938) used two methods to show that sprouting could be prevented in the potato tubers.

The basal soak method. The tubers were cut into pieces, each with one eye, and placed, eyes up, in a shallow dish. The pieces of tuber were partly covered with solution (125 cc for 12 pieces) and allowed to stand at approximately 50°F for 1 to 3 days. They were then drained and planted. The regulator used was potassium salt of NAA at 20 ppm. The potassium salt of IAA proved to be ten times less effective than potassium salts of NAA.

Vapour treatment method. Guthrie (1938) recommended the use of methyl ester of naphthaleneacetic acid (MeNA). This is sufficiently volatile to be used as a vapour. Moreover, it is absorbed by potato tubers in sufficient quantities to make possible the treatment of whole tubers as well as tuber pieces. The vapour treatment consists of dissolving the ester in acetone, pouring it on filter paper, and after evaporating the acetone, placing the filter paper with the tubers in a closed but not sealed container.

This vapour treatment was later modified by Denny for commercial use by passing the vapour through the stored tubers. It can also be done by dusting tubers with talc containing NAA. The colour of the tuber changed due to talc which is undesirable from the commercial point of view.

Denny (1942) induced dormancy in potato tubers with ethylene chlorohydrin. He found that the potatoes treated with MeNA absorbed some amount of the chemical which was reduced on cooking.

Thomes and Riker (1945) revealed that NAA treatment did not affect the taste of the tubers and if used in higher concentration was non-toxic to the animals. Gandarillas and Nyland (1949) noted that the seed potatoes that were treated with MeNA sprouted late in the field by 11 to 16 days. Smith *et al.* (1949) treated potato with MeNA and isopropyl ester of 2,4,5-T in dust form. Both the treatments reduced sprouting but greater retardation was due to MeNA treatment.

Bradley and Dean (1949) concluded that MeNA did not prove good in potatoes which had broken dormancy. Satisfactory results were obtained by the application of NAA and its sodium salt at the rate of 9 g per bushel.

Emilsson *et al.* (1952) tested the efficacy of TCNB (2,3,4,5,6 tetrachloronitrobenzene) and noted strong inhibitory effect when used at the rate of 12 mg per 100 kg of potato and the loss due to the diseases was also reduced. Kryut and Veldestra (1951) tried the compounds of naphthalene series. MeNA gave promising results when used at the rate of 0.015 and 0.030 g per kg of tubers. Humberg (1952) observed the presence of growth inhibitors in the peel which disappeared at the end of dormant period.

Garay and Pasquale (1952) treated potatoes with fusare at a rate of 4,500 g per ton of potato for minimizing the sprouting losses. Ellison and Cunningham (1953) observed that potatoes treated with MeNA were more susceptible to *Fusarium* dry rot. No incidence of dry rot was noted with the tubers treated with TCNB. This chemical was found to be more effective in controlling the sprouting when used in bins of 10 or 25 bushel capacity. It proved ineffective when treated potatoes were exposed to open air.

Marth and Schultz (1952) dipped potatoes in 1 per cent IPC solution and found it to be a good sprout inhibitor. Dusting with sulphur treatment with 1 per cent mercuric chloride solution also inhibited sprouting and lessened losses due to rotting.

The problem of excess sprout growth in storage would be further simplified if some substances sprayed on the plants in the field would retard sprouting subsequently in storage without adversely affecting the total yield and quality of tubers.

Smith *et al.* (1949) observed that the field application of 2,4,5-T retarded the sprout growth in potato. Paterson *et al.* (1951) reported that the sprays of MH at 500, 1,000 and 2,500 ppm applied to potato plants, 1–7 weeks before harvest, were effective in prolonging dormancy of tubers held in storage for 7 months at 7°C and 13°C. In other experiment, Smith *et al.* (1949) sprayed potato with TCPA and sodium naphthaleneacetate. Sprout inhibition was more with TCPA than sodium naphthalene acetate. Various workers (Smith *et al.*, 1947; Ellison and Smith, 1948) applied 2,4-D, MeNA and IAA to potato plants. MeNA at the rate of 4,000 ppm was found much more effective, while at 10,000 ppm it proved toxic and yield was reduced considerably.

Onion. The effective treatment of onions is made more difficult by the protected position of the growing point inside the onion bulb; consequently the only successful treatment is the foliar applications of suitable auxins.

Trial of plant growth regulators. MeNA and 2,4,5-T which are commonly used for sprout inhibition in potato are not effective with onions due to the submerged growing region. Wittwer and Sharma (1950) studied various growth substances, as means of prolonging the storage life of onions.

Treatments	*Concentrations (ppm)*	*Weight of sprouts*	*Percentage of storage loss from*	
			sprouting	*breakdown*
Sodium salt of a-naphthalene acetic acid	1,000	64.7	23	38
,,	5,000	36.8	22	40
2,4,5-trichlorophenoxy acetic acid	10	67.4	23	35
,,	50	68.1	28	46
Sodium salt of naphthoxy acetic acid	500	22.2	19	48
,,	2,500	45.3	14	49

Benzo-thiozol-2 oxy-acetic aci	500	40.4	20	48
,,	2,500	53.6	30	44
Maleic hydrazide (MH)	100	31.7	26	40
,,	500	3.9	10	21
,,	2,500	0.0	0	15
No treatment (control)		40.5	19	26

Observations were made after the onions had been held in storage for 5 months. No sprouting was evident on bulbs that had been sprayed with 2,500 ppm of MH and there was a significant reduction in sprouting with 500 ppm. Some decrease in loss from storage breakdown was also observed. Flavour, colour and odour were apparently not affected.

Wittwer and Sharma (1950) worked on Sweet Spains varieties of onion. During the summer and fall of 1948, the sodium salt of α-NAA and 2,4,5-T were applied separately as sprays at intervals during the growing season to the foliage of yellow Sweet Spains onions. The used concentrations were 500 to 5,000 ppm for the sodium salt of α-NAA and 25 to 250 ppm for 2,4,5-T. All these chemical treatments, including the preharvest applications of MeNA tended to stimulate rather than inhibit sprout growth and rooting. They observed an abnormality commonly termed 'blow out' development on the bases of many bulbs. The blow out condition apparently resulted from an elongation of the bases of the leaf sheath induced by the greater growth activities of the buds. Leaf bases in the elongated and enlarged regions were much thinner having sheaths not effected. Early applications of higher concentrations of both chemicals, particularly, stimulated sprouting and resulted in earlier and more storage breakdown.

Dallyn and Smith (1952), however, found that the different treatments with sodium salt of NAA applied to the foliage of onion reduced sprouting of the bulbs in subsequent storage of 27°C. They observed that the low concentrations of sodium salt of NAA applied to the foliage of onions resulted in increased bulb yield. Concentrations of sodium salt of α-NAA used were 500, 1,000 and 3,000 ppm.

It is thus clear that the application of the maleic hydrazide is the only solution to check sprouting in onion.

Wittwer and Sharma (1950) found that among the bulbs that had been treated with 2,500 ppm MH, no sprouting was evident and breakdown also significantly decreased. Flavour and colour were apparently not affected. Wittwer and Paterson (1951) stated that the preharvest foliar sprays of 0.25 per cent MH applied to Early Globe Brigham and Yellow Globe onions reduced sprouting in a 16 -10 weeks storage test at 0°C and 5°C. Wittwer and Sharma (1950) observed that at the end of the first month all MH treatments appeared equally good; however, all later readings suggested that the 2,500 ppm and 3,000 ppm treatments were better than 2,000 ppm, as would be evident from the table given below:

MEAN PERCENTAGE OF MARKETABLE BULBS IN STORAGE

Treatments	*1st month*	*2nd month*	*3rd month*	*4th month*
2,000 ppm	88.55	51.99	33.70	26.82
2,500 ppm	83.80	58.00	39.95	36.55
3,000 ppm	83.21	59.17	39.06	30.20
Control	66.56	30.65	15.82	7.82
Discarded	—	2.00	12.50	10.00

So the application of MH 2,500 ppm to 3,000 ppm is the best and a desirable one to check sprouting in onion. Later studies of Wittwer and Paterson (1951), Isenberg (1951), Rehm (1954) and Schoene and Hoffman (1949) proved the efficacy of MH in this aspect.

In recent experiments, Cifferri (1953) sprayed Maggialiola onion with 0·2 per cent solution of sodium salt of MH and observed complete inhibition of sprouting in storage.

Time of application. According to Wittwer and Paterson (1951), the time of application of MH to the growing onion crop is very important. Effectiveness of the chemical is dependent upon its absorption by the leaves and translocation to the bulbs. Accordingly, the leaves must be alive and green. However, if the treatment occurs too early in the season when the onions are still growing rapidly, hollow or pulpy bulbs result, which keep very poorly in storage. Thus with onions, MH (2,500 ppm) should be applied when the bulbs have matured, but the tops are yet green. This is usually so 1–2 weeks before harvest.

Use of gamma irradiation. Besides the use of MH, Sawyer and Dallyn (1956) had observed that in case of onions a gamma irradiation dosage of 8000 *r* for 48 hours had completely inhibited sprouting. A dosage of 4000 *r* prevents sprouting of bulbs held at 18°C.

CHAPTER VIII

CHEMICAL INDUCTION OF PARTHENOCARPY IN FRUIT AND VEGETABLES

INTRODUCTION

In 1902, Noll, recognizing the similarity between seedlessness in fruits and parthenogenesis, introduced the term 'parthenokarpic' to denote the seedless condition, and this term is now in general use. Although Noll considered that perhaps all seedless fruits should be included under this term, whatever the cause of seedlessness, he restricted it to fruits produced without pollination or other stimulation. At present, the term parthenocarpy is being used to denote production of fruits without fertilization, and also production of seedless fruits as a result of fertilization but with early abortion of embryo. Stout (1936) has used the term 'stenospermocarpy' for the later.

PHYSIOLOGICAL BASIS OF PARTHENOCARPY

The success in inducing parthenocarpic fruit development by the use of pollen of unrelated species, sterile pollen and pollen extracts (Massart, 1902 ; Hartley, 1902 ; Fitting, 1909, 1910 ; Yasuda, 1933, 1934, 1936) and the discovery that the pollen contains auxin (Laibach, 1932 ; Thimann, 1934) indicates that auxin is responsible for such induction. The success of artificial application of growth-promoting substances or auxins to the pistil (Gustafson, 1937 ; Gardner and Marth, 1937) also verify the above statement.

Suggestions have been made that auxin comes from pollen or the developing seeds (Dollfus, 1936 ; Gustafson, 1937, 1938). In fact, pollen tube brings into the ovary something (auxin) which stimulates the ovary to grow into a fruit. This view has been strengthened by the findings of Meyer and Anderson (1956) who found less growth hormone in female flowers before fertilization than afterwards. Muir (1942) found increased auxin content in the ovary after pollination. But whatever auxin the pollen tube supplies to the ovary is not enough to cause continued growth (Gustafson, 1939). This view is supported by Gardner and Marth (1937), who reported that four sprayings gave better set than a single spray of auxin. Where does then this additional auxin come from ?

Gustafson proposed that growth hormones might be synthesized by the developing seeds, perhaps the embryo. But again what happens in case of the naturally parthenocarpic fruits where no seeds are formed ? Gustafson (1939) found that ovaries in bud stage in the parthenocarpic varieties of lemon, orange and mandarin had higher auxin content than those in seeded varieties and from this he concluded that ovules or the ovary itself may produce an unusually large amount of auxin. Even a little auxin added in the right place, as the ovules, would be sufficient to cause them to grow and set up auxin centres from which auxin might diffuse into the ovary and thus auxin is present in the ovary even if seeds are not produced. This hypothesis has been strengthened by the fact that changes in growth patterns and increased fruit size may be induced by auxin application to such fruits as the apricot (Crane and Brooks, 1952), grape (Weaver and Williams, 1950), prune (Harris and Hansen, 1955) and fig (Crane and Blondeau, 1949). Luckwill (1948) also pointed out that auxins were the key factors in initiating growth of fruits. For that matter, as stated by Leopold (1962), Luckwill (1957) and Nitsch (1952), fruits containing numerous ovules will set parthenocarpic fruit by natural auxins, whereas, those having single ovule should neither be parthenocarpic nor responsive to exogenous growth regulators. But the parthenocarpy induced in apricot by Primer and Crane (1957) is sufficient to criticize this hypothesis.

It is likely that natural auxin is deficient in varieties where parthenocarpic fruits have never been obtained and the developing seeds supply auxin to produce non-parthenocarpic fruits (Gustafson, 1939). Moreover, Thompson (1961) postulated the production of an inhibitor by the unfertilized ovule whose effect must be overcome by auxin before fruit growth can proceed.

The application of auxins to unpollinated flowers of most species, with few exceptions, has failed to bring about parthenocarpy. No correlation between auxin content and fruit growth was found in fruits such as apple (Luckwill, 1948), fig (Crane and Blondeau, 1949), grape (Coombe, 1960) and strawberry (Nitsch, 1956). These evidences indicate that auxin alone is not the only factor which is necessary for fruit set, but one or more additional factors are involved.

Went (1938) considered that auxin acts in such a way as to cause other substances which he calls 'calines' to move to the part of the plant where growth takes place. And he tentatively named the substances which causes fruit growth as 'Carpocaline.

The fact that development of many fruits like apple involves a fairly protracted period of cell division, as against cucurbits and many other fruits where fruit growth is mainly by cell enlargement, led Luckwill (1959) to predict that cell division factors of the type present in coconut milk are required in addition to other types of hormones for fruit growth in many plants.

The fact that GA-like substances are present in the endosperm of many species (Phinney *et al.*, 1957) indicate that GA or GA-like substances may be essential for fruit growth and development. This hypothesis has been amply justified by the positive results obtained by GA in inducing parthenocarpy in peach, apricot and almond (Crane *et al.*, 1960), Bing cherry (Rebeiz and Crane, 1961), grapes (Pratt and Shanlis, 1961), Clementine mandarin (Soost and Burnett, 1961), guava (Teaotia *et al.*, 1961 ; Shanmugavelu, 1962), and apple (Luckwill, 1960 ; Davison, 1960 ; Dennis, 1962).

Luckwill (1959) and Abbott and Luckwill (1962) reported three types of naturally occurring growth hormones supplied by developing seeds, namely kinins, gibberellins and auxins, and that these must be supplied artificially for production of parthenocarpic fruits. The kinins are essentially the cell division hormones and recent tissue culture work suggests that they are important for the early growth of fruits like apple, in which there is a phase of rapid cell multiplication lasting for 3–4 weeks after bloom. Gibberellins and auxins promote growth by cell expansion, probably acting in conjunction with one another. Auxins also inhibit abscission and retain the fruit longer on the tree.

CHEMICAL USED TO INDUCE PARTHENOCARPY

The results obtained by application of some of the chemicals which are known as growth regulators have been very promising and at times even spectacular. These include some indole compounds : acetic, butyric and propionic acids (Gustafson, 1936 β-naphthoxypropionic acid), some naphthalene compounds (naphthalene acetic, butyric and propionic acids) and some derivatives of phenoxy acids : 2,4-D and 2,4,5-T etc. Besides these, some other chemicals such as acenaphthalene, oestrome sulphariclamide phenyl acetic acid and skalatol are others which have induced physiological responses. It has been observed that chemical structures which impart physiological activity to the compound are of diverse structure and there is no grouping or structural feature common to them all. Pyrrole α-carboxylic and pyrrole acetic acid were shown to have slight activity (Gustafson, 1988) but they are of no practical value.

Among the many auxins which have been used, p-chlorophenoxyacetic acid (4-CPA) and β-naphthoxyacetic acid (BNOA) have emerged as the most effective and most widely used. These are both fairly weak auxins and both have relatively little epinastic effects on the leaves. Redemann *et al.* (1951) found that the ester is approximately four times more effective in setting fruit than the free indole acetic acid. Likewise, indoleacetonitrile was found to be more effective than the free acid (Bentley and Bickle, 1952). Wood and Fontaine (1952) report amide derivatives of 2,4-D with D-amino acids to be effective without causing epinastic deformations, whereas the amide derivatives with α-amino acids are as epinastic as 2,4-D itself.

Epinastic agents which are not auxins are effective in fruit-set as well as auxins. Derivatives of phthalmic acid (Hoffmann and Smith, 1949) and benzoic acid (Zimmerman and Hitchcock, 1942) have induced fruit set.

Recently, GA alone (Modlibowska, 1960, 1961 ; Kononov, 1960 ; Davison, 1960 ; Luckwill, 1960, 1962 ; Crane *et al.*, 1960 ; Pratt and Shanlis, 1961 ; Teaotia *et al.*, 1961 ; Soost and Burnett, 1961 ; Bradley and Crane, 1962 ; Shanmugavelu, 1962) and GA in combination with auxin (Jackson and Prosser, 1959 ; Rebeiz and Crane, 1961) have been found effective in inducing parthenocarpic fruit set in various tree fruits.

The selection of auxin concentration to be used in practice must take into consideration the injurious effects that they may have on the plant, the undesirable effect that the chemical may have on the fruit, and any other special consideration for different fruits. The concentration to be used varies with fruits, climate, chemical and other conditions of use.

TECHNIQUES OF APPLICATIONS

Lanolin Paste. The method as originally used by Gustafson (1936) consisted in mixing the chemical with lanolin and this paste was applied to the stigma of the pistil or to the cut surface of the style after the stamens had been carefully removed from the bud. Strong (1941) modified the method ; she merely cut the bud or the recently opened flower immediately above the ovary and smeared the paste on this surface. This procedure requires less time.

Since the growth substances readily dissolve in molten lanolin paste, it has been a convenient medium for supplying the growth substances. Its use, however, is restricted to cases where the number of flowers to be treated is small. Extra care should be taken to restrict the application of hormone in lanolin paste to the desired spot only, as the results are likely to be unfavourable if any unduly large area of ovary is smeared with the preparation. It has been recommended that for finer work, lanolin should be purified to get uniform results (Redemann *et al.*, 1950).

Spraying. Growth substances can be dissolved in water or prepared in emulsion from the spraying. This mode of application has been found to be very suitable for glass-house spraying to promote fruit set (Zimmerman and Hitchcock, 1941 ; Howlett, 1941 ; Swarbrick, 1945 ; Gustafson, 1942 ; Dennis, 1962). The spray method is, however, less effective than lanolin paste method.

Soil Application. Gardner and Marth (1937) and Randhawa and Thompson (1948) have succeeded in inducing fruit set by watering or spraying growth regulators on the soil below the plant. Zimmerman (1942) also induced parthenocarpy by adding substituted phenoxy compounds to the soil.

Aerosol Method. It has been found to be convenient as well as effective to apply the growth substances after dissolving them in liquified gases. When such a solution is released through a fine nozzle, the gas leaves dissolved growth substances in finely suspended form. The method is useful for greenhouses (Hamner *et al.*, 1944 ; Howlett and Marth 1941).

Vapour Method. In greenhouse crops, the growth substance is applied by evaporating it on the hot plate. The quantity of the chemical to be used should be determined with great caution as overdoses are likely to induce undesirable effects on the plants (Zimmerman and Hitchcock, 1939 ; Strong, 1944).

In Carbowax. The growth substances can be dissolved in carbowax and stored. The desired dilution can be prepared at the spot by dissolving the carbowax tablet in requisite quantity of water. This eliminates the need for transporting the chemicals in solution form.

Injections. In order that the injection method may be used with success, it is first necessary that the pedicel be large enough so that the needle diameter is small in proportion to the diameter of the pedicel. Secondly, the ovary and perhaps also the calyx tissues should have numerous intercellular air spaces (Yasuda, 1934; Gustafson. 1938).

TIME OF APPLICATION

The time of application depends upon the method of application, environmental conditions and the condition of the buds or flowers on the tree. The chemical in lanolin paste is applied at pre-anthesis stage on the excised pistil (Teotia *et al.*, 1961). The spray applications are best done on emasculated flowers at full bloom, checking pollination by bagging or emasculation (Luckwill, 1960 ; Crane *et al.*, 1961).

Dikshit (1958, 1959) found that in *Annona squamosa*, treatments in August at pre-anthesis stage was better than in April and May because the buds in the former case were robust. Gustafson (1942) recommended that the spray should be kept off the foliage and the growing point and the spraying should be done when the last flowers are opening.

RESEARCH WORK DONE ON FRUITS AND VEGETABLES

Apple. Early attempts to induce the development of parthenocarpic fruits or improve fruit set in apples and pears by the application of growth substances were almost invariably successful (Gardner and Marth, 1937); Burkholder and McCown, 1940: Greene, (1943). Swarbrick (1945) sprayed apple trees, after a severe frost which had occurred when the young fruitlets were already beginning to grow and which killed the embryos and blackened the centres of the young fruits. The spray used contained 55 ppm IBA, 5 ppm α-NAA, 5 ppm 2,4-D and 60 ppm α-NAA, giving a total growth substance content in the solution of 75 ppm. This treatment had little effect on the fruits of Cox's Orange Pippin, but with Miller's Seedling the fruits remained on the tree and showed appreciable swelling, whereas, practically all the fruits dropped from unsprayed trees. Later the fruits stopped growth but many of them attained a diameter of from 3.71 cm to 5.08 cm. Luckwill (1946) isolated a hormone-like substance from developing seeds of apple, and this substance was effective in inducing parthenocarpy in tomato.

Woodcock (1947) indentified the crystalline substance obtained by Luckwill from apple seed as phloridzin and stated that this substance is present in quantities as high as 8 per cent of the fresh seed weight up to four weeks petal fall and decreases to one per cent after 8 weeks. But the relationship between this substance and the hormone obtained from the same source was not worked out.

Osborne and Wain (1951) obtained preliminary success in inducing parthenocarpy in apple by application of α-phenoxypropionic acid (100 ppm). Gorter and Visser (1958) reported that the plant regulator treatments to Winter Gold Pearmain and Laxtons Superb apples, which produce parthenocarpy naturally, also induced slightly higher production of parthenocarpic fruits than the control.

Luckwill (1960) reported that aqueous solutions of potassium salt of gibberellic acid and α-2-naphthoxypropionic acid (2-NOP) at 50 ppm sprayed at petal fall stimulated early growth of apple fruit. Davison (1960) reported that GA, applied at 1 per cent in lanolin paste to the receptacles during flowering, induced parthenocarpic fruit development in Sturman, Cox's strawberry, Norman and Red Jersey apples. Spray at 4,000 ppm was al sofound effective.

Dennis (1962) tested several compounds to stimulate parthenocarpy in emasculated flowers, but only GA was effective and produced mature fruits of nearly normal size of Duchess of Oldenburg and McIntosh. Applications in lanolin paste (5,000 ppm) were more effective than aqueous sprays or injections (100-1000 ppm). 2-Chloro-4-fluorophenoxyacetic acid was effective as supplemental spray in preventing fruit drop, but it inhibited fruit growth in several varieties. Single spray of GA (200-500 ppm) promoted fruit growth in two varieties, but phloridzin spray and injections did not do so.

Pear. Sereisky (1938) induced seedless fruits in pear by IAA (0.1 per cent, 0.5 per cent or 1.0 per cent). Lewis (1946) studied the action of naphthaleneacetamide on the process leading to fruit development in a number of species including *Pyrus communis* and concluded that parthenocarpy could be induced in many seeded fruits only, by application of growth substances. Osborne (1949) sprayed emasculated flowers of Pitmaston Dutchess pears with α-2 naphthoxypropionic acid and produced seedless fruits which were normal in appearance. The parthenocarpic fruits induced in Dr Jules Guyot pear variety were somewhat smaller than the normal fruits. Osborne and Wain (1951) obtained parthenocarpic fruits in some pear varieties with plant growth regulators. Batjer and Uota (1951) found that the seed content of Bartlett pears was affected in an orchard which was not cross pollinated following sprays with 2,4,5-T. Griggs *et al.* (1951) found higher percentage of seedless fruits in pears after sprays with 2,4,5-T at full bloom. Trees of both Laxton's Superb and Williams pears set seedless fruit after GA spray at 50 ppm on emasculated flowers at petal fall. More fruit was set with GA alone than with GA plus 2-NOP (Luckwill, 1959). Luckwill (1960) further stated that even a single application of GA carried full crop of parthenocarpic fruits. Modlibowska (1960, 1961) reported that GA treatment on pears with or without frost damage may have commercial possibilities. Dwarf pyramid pears damaged by frost were sprayed with GA (Luckwill, 1962) at concentrations from 5 to 200 ppm, applied at 'white bud', 8 days after damage and others at full bloom. The varieties tested were Williams and Laxton's Superb. About 80 per cent of the flowers were damaged by frost and thus unsprayed trees carried a poor crop. Spraying at full bloom with 80 ppm GA gave best results.

Stone Fruits. Parthenocarpic fruit sets of 5 to 10 per cent were obtained in three varieties of apricot from 7½ to 50 ppm (Primer and Crane, 1957). Crane *et al.* (1960) used aqueous solutions of 50, 250 and 500 ppm GA (with 0.05 per cent Tween 20) at full bloom, and 8 days later with almond, apricot cherry, plum and peach. None of the treatments were effective in inducing parthenocarpy in cherry and plum. GA at 500 ppm, applied twice, brought about parthenocarpic set of 11.8 per cent in almond and 15.5 per cent in apricot. Parthenocarpy in peach was induced by all concentrations of GA whether they were applied once or twice. Aqueous solutions of 250, 500 and 1,000 ppm of GA applied as spray to emasculated J.H. Hale peach blossoms promoted parthenocarpic fruit sets of from 53.8 to 69.3 per cent (Crane *et al.*, 1961). Aqueous solutions of GA plus 2,4-dichlorophenoxy acetyl methionine (2,4-DM) at 2 days after full bloom was effective in inducing parthenocarpic fruit development in Bing cherry (Rebeiz and Crane, 1961). Bradley and Crane (1962) reported inducement of parthenocarpy in peaches by spraying emasculated flowers on large scaffold branches with K GA at 50, 250 and 500 ppm.

Avocado. Stewart and Hield (1951) tried triethanolamine salt and isopropyl ester of 2,4-D and butyl ester of 2,4,5-T at various concentrations. Parthenocarpy was induced by using 2,4-D spray in April. Treatment of Fuerte avocado tree with sprays of n-metatolylphthalmic acid at 0.25, 0.3, 0.4 and 0.5 per cent increased the number of small, slender seedless fruits. GA (100 ppm) also increased the number of seedless fruits (Hield, 1961).

Citrus. Pomeroy and Aldrich (1943) applied NAA, IBA, IAA, furacrylic acid and calcium furoate at the flowers of Washington Navel orange and Marsh grapefruit. The treatments did not increase the percentage of flowers setting fruit. Soost and Burnelt (1961) increased the set of seedless fruits of Clementine mandarin in the absence of pollination. Randhawa *et al.* (1964) obtained parthenocarpic fruit set in grapefruit (60 to 90 per cent) by spraying the emasculated flowers with GA ranging from 25 to 1,000 ppm.

Guava. Balasubramaniyam and Rangaswami (1959) induced parthenocarpy in Allahabad Round guava when stigmas of emasculated flowers were treated with aqueous extracts of crushed pollen. Rangaswami and Kaliaperumal (1960) produced parthenocarpic fruits in the same variety with water and other extracts of pollen, NAA, NOA and 2,4-D. They reported indole-like compounds to be present in the parthenocarpic fruits. Shanmujavelu *et al.* (1961) reported that the 'pollen hormone' in Allahabad Round guava, which can produce parthenocarpic fruits appeared similar to IAA. Teotia *et al.* (1961) applied GA in lanolin to emasculated flower buds at 100, 500, 1,000 and 10,000 ppm. The buds treated at 100 and 500 ppm dropped, those treated at 1,000 ppm fell after small fruitlets were formed and of those treated at 10,000 ppm two-thirds grew to fully ripe fruit.

Shanmujavelu (1962) treated the excised pistils of emasculated flowers with KGA in lanolin (8000 ppm) in Allahabad Round, Lucknow, Red fleshed and Seedless guava varieties. All the varieties produced seedless fruits, the percentage parthenocarpic sets being 90, 70, 80 and 80 respectively. GA treatment increased the fruit size in Allahabad Round, but decreased in Lucknow and Red fleshed, whereas, the fruit size remained normal in Seedless. The parthenocarpic fruits in these varieties showed characteristic 6–8 prominent ridges on the surface and swelling at the calyx end.

Fig. Blondeau and Crane (1948) and Crane and Blondeau (1949) tried to produce parthenocarpic figs by using 25 ppm 2,4,5-T on unpollinated cyconia and obtained fruits which, though devoid of achenes, were normal in size, sugar and colour. Later they (1950) obtained encouraging results with 4-CPA. Blondeau and Crane (1950) tried a number of growth substances and found IBA, NAA and 2,4,5-T to be the most effective. 4-CPA was most encouraging because of lack of toxicity, low concentration needed, and the comparative low cost of the chemical. Crane and Baskaya (1951) produced parthenocarpic figs using 4-CPA and Y-indole-3-n-butyric acid. Crane (1952) observed growth regulator specificity in the development of ovary wall in parthenocarpic figs. Crane and Campbell (1959) sprayed fig shoots with GA at concentration from 25-1,000 ppm, and then prevented caprification. A high positive correlation was found between the length of new shoots induced, the number and length of internodes and the concentrations of GA used. All dosages, except the lowest, produced 100 per cent parthenocarpic fruitset.

Date Palm. Nixon and Gardner (1939) attempted to influence the development of the ovaries of date palms by applying growth substance preparations, but were unsuccessful.

Tomato. Zimmerman and Hitchcock (1941) found that naphthoxyacetic acid has several advantages in the practical production of seedless fruits. Seedless fruits, larger than the seeded ones, were obtained when BNOA was applied at 0.25 and 1.0 per cent (Gustafson, 1942). Treccani (1948) obtained parthenocarpic fruits by 10 ppm 2,4-D, but at 25 ppm this chemical was found to be exceedingly potent for inducing parthenocarpy (Villariba and Capinpin, 1948).

Egg Plant. Villariba and Capinpin (1943) found 2,4-D at 25 ppm to be quite effective in setting fruits.

Pepper. Gustafson (1941) found that NAA at 2 per cent, in lanolin, was most effective in producing seedless fruits which were somewhat smaller than the normal fruits.

Cucurbits. Good results were obtained in *C. moschata* by Mori (1947) when flowers were treated with 0.02 per cent of potassium salt of NAA. Wittwer and Bukovac (1957) were able to induce parthenocarpic fruits to some extent by applying Gibberellin and heteroauxin in lanolin. Gonzalez Alonson (1955) treated flowers of water melon with several growth regulators but no treatment resulted in complete seedless mature fruits. The best results were obtained with 2,4-D followed by potassium salt of NAA.

EFFECTS OF PARTHENOCARPY

The seedless fruits differ from the normal seeded ones in setting, shape and size, maturity, chemical composition and histological details. Further, the normal seeded fruits and parthenocarpic fruits exert a profound effect on the other parts of the parent plant.

Wong (1940) observed that seedless fruits of normal size could be produced with growth substances without objectionable seedcoat in some plants and varieties. Gustafson (1940) showed that seedless fruits tended to be smaller in size than the normal seeded ones. Rebeiz and Crane (1961) reported that the parthenocarpic Bing Cherry fruits were significantly smaller in size than the pollinated controls. According to Davison (1960), parthenocarpic apple fruits were smaller and misshapen. Shanmujavelu (1962) got smaller fruits in Lucknow and Red fleshed varieties of guava, larger in Allahabad Round and of the same size in Seedless due to parthenocarpy. Similar type of varietal differences have been reported by Dennis (1962) in apple. Crane *et al.* (1961) also got smaller fruits in peaches but they were elongated with longer pit and thick flesh at stem and blossom ends.

In contrast to these reports, Crane and Blondeau (1942) got parthenocarpic figs of normal size and colour. Crane *et al.* (1960) obtained normal sized parthenocarpic apricot, almond and peach.

Bredermann (1951) suggested that deformity in some pears may be due to parthenocarpy. Luckwill (1960) also obtained elongated fruits with excessive puckering around eye in pears. Mis-shapen fruits also develop in apple (Davison, 1960) due to parthenocarpy. Ridging and elongation in parthenocarpic fruits have also been reported in guava (Teotia *et al.*, 1961 ; Shanmujavelu, 1962) and peach (Crane *et al.*, 1961).

Fruit-setting. Gustafson (1942) reported that the setting in treated fruit was at least as high as in the normally pollinated flowers. The early rate of growth was faster in the treated fruits. This rate, however, slowed down at a later stage.

Griggs *et al.* (1951) induced all pear flowers in a cluster to set as against 1-3 per cent in control. Luckwill (1959, 1960) increased the set in frost-damaged pear by plant regulators. Crane and Campbell (1959) obtained 100 per cent parthenocarpic set as against 82 per cent natural set in figs. In stone fruits also the set was raised to 63-73 per cent from 42 per cent in open-pollinated blossoms (Crane *et al.*, 1960). Soost and Burnett (1961) in Clementine mandarin and Crane *et al* (1961) in J.H. Hale peach got greater set by plant growth regulators.

Contrasting to these, reduced sets of fruits have also been reported by Hield (1961) in avocado, Dennis (1962) in apple and Crane *et al.* (1961) in Bing cherry. In Bing cherry, only 27.3 to 38.8 per cent fruit set could be obtained as against 43.3 per cent in open-pollinated blossoms.

Maturity. Advanced maturity due to induction of parthenocarpy has been reported by Blondeau and Crane (1948), Crane and Blondeau (1949), Crane (1953) and Basso (1960) in fig, by Crane *et al.* (1960) and Rebeiz and Crane (1961) in stone fruits, by Luckwill (1960) in apple and pears and by Teotia *et al.* (1961) in guava. But Davison (1960) observed normal ripening in apple by GA treatment. Besides, Gardner and Marth (1937) in holly and Clark and Kerns (1943) in pineapple noted delayed ripening by NAA treatments.

Quality of Fruits. Condit found that seedless fruits of *Diospyros kaki* were light coloured and astringent until quite soft and ripe. But the seeded fruits were non-astringent even when hard. He further observed in 1920 that uncaprified figs had higher sugar content than the caprified ones. Crane and Blondeau (1949) observed that the parthenocarpic fruits were normal in sugar content, but Basso (1960) found that figs were inferior in quality than those ripened naturally. Davison (1960) reported that treated fruits in apple were normal in colour and quality. According to Luckwill (1960), parthenocarpic pears were of acceptable market quality. The parthenocarpic guavas were found richer in ascorbic acid content by Teotia *et al.* (1961).

Histological. Crane and Baskaya (1951) observed that the development of achenes in fig cyconia differed when 4-CPA and Y-IBA were used. In the former, the endocarp of achenes remained parenchymatous instead of getting sclarified as in normal case. When the latter was used the achenes had no endocarp. Crane (1952) observed three distinct deviations from the normally developed cyconia when he used benzothiazole-2-oxyacetic acid : (i) achenes with no endocarp, (ii) achenes with unsclarified endocarp, and (iii) the completely sclarified endocarp. Embryos were absent in all the three types of deviations.

Primer and Crane (1957) explained that parthenocarpic fruits had fewer cell layers and smaller cells and as a result their average diameter was only 40 per cent of the fertilized fruits in apricot.

Other Effects. Besides, the chemicals sprayed to induce parthenocarpy may have some abnormal, undesirable and epinastic effects on the plant. They are : (a) leaf chlorosis and their epinastic deformations (Hield, 1961) ; (b) deformation of fruits (Bredermann, 1951 ; Davison, 1960; Teotia *et al.*, 1961 ; Shanmujavelu, 1962) ; (c) long shoot formation from spurs of cherry and plum, and internode elongation in peach by GA (Crane *et al.*, 1960) ; and (d) premature softening of parthenocarpic fruits by the formation of fragile carpellary wall.

USEFULNESS OF CHEMICAL-INDUCED PARTHENOCARPY

Overcoming Limitations of Fruit-set. Set in fruit crops is affected by all those factors which affect pollination and fertilization. Self unfruitfulness due to unisexuality, self-incompatibility, dichogamy, cleistogamy, etc., necessitate cross pollination and thus the pollinators and pollinizers are often used. The activity of pollinators is also affected by environmental condititions. To get compatible and proper pollinizer is difficult and sometimes uneconomical. In fruits like the fig special type of pollination is accomplished, fertilization may fail to take place due to many reasons. Fruit set is also affected by lack of nutrient material. This is clear by the findings of Dikshit (1958) where decrease in the number of leaves affected the set and size of pineapple fruits.

Luckwill (1959) suggested that GA is most effective to induce fruit set on frost-damaged pears. Abott and Luckwill (1962) stated that from economic point of view interest centres around the possibility of inducing parthenocarpy in certain fruit crops by means of sprays of growth to substances as an alternative of pollination. And he adds that the value of fruit-setting sprays is primarily as an insurance against disasters (frost damage, high temperature and insect damage) rather than as a substitute for normal pollination.

Shortening the Time of Maturity. Blondeau and Crane (1948) explained that 2,4,5-TP raised the hormonal level in the plants to such a point that the mobilization of stored reserves in fruit was almost immediate and thus figs matured in 60 days as against 120 days period required normally.

CHAPTER IX

GIBBERELLINS

INTRODUCTION

Gibberellins, a group of naturally occurring growth regulators, have aroused the interest of the horticulturists because of their spectacular effects on plants. These compounds strikingly stimulate the growth of many plants, promote flowering in some cases, and cause a variety of other interesting morphological and physiological responses. Their use opens up new avenues of approach to botanical problems, and many of their effects promise to be of economic importance in agriculture and horticulture. Though these substances have a long back history, it is only within the last ten years that the growth-regulating properties of the gibberellins have attracted the attention of the horticulturists all over the world.

DISCOVERY OF GIBBERELLINS

Gibberellin was first discovered by late Elichi Kurosawa in 1926 in Japan. A rice disease attracted his attention because of the peculiar fact that diseased plants often became 50 per cent or more taller than their healthy neighbours in the initial stages of the malady. Fromth is characteristic the colloquial name 'bakanae' was derived. The malady is due to a fungus whose sexual form is known as *Gibberella fujikuroi* and the more common asexual stage is known as *Fusarium moniliforme.*

Kurosawa postulated that some metabolite of this fungus might be responsible for the stimulated seedling growth and in 1926 he succeeded in obtaining a filtered fungal extract which caused growth stimulation of both rice and maize seedlings. Thereafter, a number of Japanese chemists tried to concentrate and purify the substance, but Yabuta and Hayashi first isolated a highly active crystalline substance in 1939 and designated it as 'Gibberellin A' (Bvian, 1961).

CHEMISTRY OF GIBBERELLINS

After the discovery of gibberellins, preliminary work was started in Japan to find out its chemical nature and structural formula. Cross (1954) reported that the Japanese studies first established the nature of gibberellin skeleton by showing that gibberene was obtained by selenit dehydrogenation of gibberellins, A, B or gibberic acid.

After intensive research in this regard it was soon realized that the original Japanese gibberellin A was a mixture and that the first pure

gibberellin was called gibberellic acid by Imperial Chemical Industries group (Cross, 1954). Simultaneously, tfrom he Biological Warfare Centre at Camp Detrick, Maryland (U.S.A.), two gibberellins were reported, one named gibberellin, which was similar to gibberellic acid, and the other was similar to Japanese gibberellin (Stodola *et al.*, 1955).

The general properties of gibberellins as given by Phinney and West (1960) in their elaborate review are stated in the following table.

GIBBERELLINS FROM CULTURE FILTRATE OF GIBBERELLA FUJIKUROI

Name	Other names	Molecular formula	Molecular weight	M.P.
Gibberellin A_3	Gibberellin X Gibberellic acid	$C_{19}H_{22}O_6$	346	232-235^0
Gibberellin A_1	Gibberellin A Dehydrogibberellic	$C_{19}H_{24}O_6$	348 350	255-268^0 - (dec)
Gibberellin A_2		$C_{19}H_{26}O_6$	350	-(dec)
Gibberellin A_4		$C_{19}H_{24}O_5$	332	220^0 (dec.)

The different structural formulae of the four gibberellins obtained from the culture filtrate of *G. fujikuroi* as reviewed by Phinney and West (1960) are shown herein.

The English group has advanced structure I and II for GA_3 and GA_1, respectively, while the Japanese group has proposed structures III and IV for these compounds. The Japanese have also advanced structure V for GA_2 and structure VI for GA_4.

After the discovery of GA_5, Mac Millan *et al.* (1960) proposed the structure VII for Gibberellin A_5. But as a result of further research now, as many as six gibberellins from the fungus *G. fujikuroi* have been reported and these are gibberellin A_1, A_2, A_3, A_4, A_7 and A_9 (Cross *et al.*, 1961).

There is a difference of opinion in the structures of GA_3 and GA_1 between the English group and Japanese group relative to the position of lactone ring in ring A (Phinney and West, 1960). Brian *et al.* (1958) reported that the complex lactone ring present in the structure of gibberellin seems to be essential for biological activity, since the potency is lost when it is opened and gibberellic acid is formed. Gibberellin

A_1 has been shown to be dehydrogibberellic acid. GA_1 and GA_4 are chemically closely related to GA_1 and GA_3.

Of all the gibberellins, only gibberellic acid is produced by the fungus in more than trace amounts. But now an industrial fermentation process has been developed which produces gibberellic acid in high yields. It is gibberellic acid (GA_3) produced in this way which is being used in nearly all the horticultural experiments.

EVIDENCE OF GIBBERELLIN-LIKE SUBSTANCES IN PLANTS

Previously the conception was that the gibberellins were only associated with the fungus *G. fujikuroi*. The recent techniques such as chromatography, fluorescence properties, and biogrowth response with phinney maize have enabled the research workers to isolate gibberellins from a number of flowering plants.

Radley (1956) reported that nine different plant genera, representing seven families, have given same growth-stimulation as by gibberellins. Mac Millan and Suter (1958) were able to isolate gibberellin A_1 in small quantities from immature seeds of *Phaseolus multiflorus*. After further research, Mac Millan *et al.* (1960) reported four types of gibberellins, namely GA_1, GA_5, GA_6, and GA_8 from the seeds of *P. multiflorus* L. West and Phinney (1959) extracted a substance from immature seeds of *P. vulgaris* L. which subsequently was shown to be identical with gibberellin A_1. They further obtained a second substance from extracts of immature seeds of *P. vulgaris*, which had gibberellin like properties but differed in chemical and physical properties from the reported fungal gibberellins. Hence, they named it GA_5. The yields of gibberellins in all these cases were from 0.2 to 1.0 mg per kg fresh weight of the plant material.

Summary of the sources of known gibberellins

Gibberella fujikuroi	A_1	A_2	A_3	A_4			A_7		A_9
Phaseolus vulgaris (seed)	A_1				A_5				
P. multiflorus (seed)	A_1				A_5	A_6		A_8	
Citrus unshuii (shoots)	A_1								

METHODS OF APPLICATION

Several methods of gibberellin application have been adopted by the research workers of which the following may be mentioned.

Liquid Sprays. This is the most convenient method and is generally followed. Gibberellic acid is soluble in water only to the extent of 6,000 ppm. A stock solution is prepared by dissolving one gram in 95 per cent ethyl alcohol with 0.1 per cent Tween 20 and diluting with water to make one litre of solution. Dilutions are prepared from this stock solution. Gibberellic acid generally contains 91 per cent active constituent.

When a wider range of concentrations are required, potassium gibberellate (82 per cent ai), which is completely water soluble, may be used along with the wetting agent.

Lanolin Paste. This is an easy way to obtain a systematic application. A 1 per cent paste is prepared by placing 12.5 mg of the gibberellic acid into a small vial, then dissolving the acid by warming it with seven drops of a spreader and finally mixing it with one gram of melted lanolin.

Aerosols. Aerosols produce a dry spray over the entire plant leaving no powdery residue. The advantage of this method is that gibberellin is stable in the solvents used in aerosols, while it loses its activity when stored in contact with water. This method is also economical in case of a limited number of plants to be treated.

MORPHOLOGICAL, PHYSIOLOGICAL AND HISTOLOGICAL ACTION OF GIBBERELLINS

Cell Elongation. The typical action of gibberellin on higher plants is the stem elongation. Growth promotion is restricted to young tissues only, mature tissues are not influenced.

In general, rapidly growing herbaceous plants require only low amount of gibberellin and optimum level of fertilizers, especially nitrogen, for increased elongation (Pirone, 1958). Bukovac and Wittwer (1956) reported that gibberellic acid or gibberellin at the rate of 10-20 mg per plant resulted in significant elongation of internodes in pea, bean, tomato, pepper, sweetcorn, summer squash, cucumber, lettuce and cabbage grown in soil or solution cultures. Rappaport (1957) reported that gibberellin (25-40 mg/plant) induced stem elongation in tomato accompanied by an increase in fresh and dry weight of plants. Soost (1959) found that 30-60 mg/plant of gibberellic acid (GA) application to the fourth expanding leaf of tomato plants of a dwarf variety and of a normal variety produced significant increases in stem elongation in both cases. Armstrong (1958) reported that radish treated with 1, 10 and 100 ppm of gibberellin showed increase in height but produced polar leaves curled at the edges. According to Paul *et al.* (1956) 49 kinds of plants treated with GA developed longer internodes, some with very thin thread like stem, while the others with stems of greater diameter than those of control plants.

GA has no promotive effect on root initiation. But, Davis and

Kalmos (1957), Richardson (1958) and Butcher and Street (1960) have cited examples in contradiction to this belief. GA has been found to enhance the growth of the main axis and laterals of excised tomato root placed at low sucrose concentration. But higher dosage retard the elongation of roots of germinating seedlings of many species.

A few years back it was considered that GA increases the length of plant parts by cell elongation but recently it has been proved that gibberellic acid effects both cell division and cell elongation. Sachs and Lang (1961) and Basford (1961) have proved in *Hyoscyamus niger* and *Senicio* spp., respectively, that in sub-apical tissues of these plants growth occurs by cell division. Response to gibberellins in terms of cell elongation and cell division, depends upon the nature of tissue and the balance of different kinds of growth substances. GA has been found to increase the cell wall plasticity, thus creating water diffusion pressure deficit, which results in water uptake, thereby causing cell elongation.

The promotion of internodal elongation by gibberellin promises to be of some practical use. For example, gibberellin treatment has increased the yield of hemp but not the fibre length (Lona, 1956 ; Hayashi and Murakami, 1958). If fibre length can be influenced in crops like flax or cotton, such treatment could be of considerable economic value.

Induction of Flowering. Another property of gibberellins is their ability to induce flowering in some species. Different species have definite requirements of specific day length which must be met before they will form flowers. The first evidence of the induction of flowering is shown by Lang (1956) in *Hyoscyamus* by application of GA in environments under which flowers otherwise never would have formed.

Wittwer and Bukovac (1957) reported that leaf and head lettuce, endive, radish, mustard, spinach and some other long-day annuals when grown under non-inductive short photoperiods showed marked increase in stem elongation and were induced to flower and produce seed by gibberellin. In long-day plants, grown under short days, a single spray of 100 to 1,000 ppm or 20 to 100 micrograms of gibberellin per plant at various stages of seedling growth induced flowering in some cases while in others repeated treatments were required. Flowering in several plants having an obligate short-day requirement, grown under long days, has not been induced with GA (Wittwer *et al.*, 1958). They further reported that the effect of gibberellic acid on flower formation in many other facultative and obligate short-day plants as well as short day-long day species grown under inductive and non-inductive short days have by no means resolved and interesting relationships have yet to be established. Lona (1956) has reported that in some short-day plants gibberellin inhibits flowering. But, Lincoln and Hamner (1958) have shown that in some short-day plants it increases the amount of flowering without being able to initiate flowering.

In biennials, the need for cold treatment (vernalization) is essential to induce flowering. Lang (1956) discovered that this requirement could also be eliminated by gibberellin. Bukovac and Wittwer (1957) reported that several biennials, like carrot, beets cabbage, kale and collards, grown at temperatures (10°–30°C) slightly above normal were induced, to flower with foliar spray of 100–1,000 ppm or weekly dosages of 100 micrograms of gibberellin to stem species. At temperature between 15° and 18°C, gibberellin induced flowering in carrots. However, this is not invariably the case, since over-wintering grains and other plants have not yet responded satisfactorily (Lang, 1956).

Earlier flowering as a result of gibberellin treatment has been observed in plants which are photosensitive as well as in some day neutral species (Rappaport, 1957). In the latter case, flowering may result as a consequence of the plant's reaching optimum size more quickly.

Harda and Nitsch (1959) reported that application of GA induced early flowering in Japanese chrysanthemum. Gibberellin applied as a foliar spray at 10 to 100 ppm hastened flowering by 10–14 days in petunia, larkspur, English daisy, China aster and gerbera (Lindstrom *et al.*, 1957).

So, GA has been observed to induce flowering in long-day plants when grown in short-day photoperiod and removes the cold requirements of some biennials. This has been explained by Brian (1959) who mentioned that GA-like hormone which was not itself florigen was produced by precursor in light period and in dark period. GA-like hormone again reverses to precursor. However, in short-day plants when grown under long-day photoperiods, more quantity of GA-like hormone is produced which is not conducive to flowering.

Leaf Expansion. Paul *et al.* (1956) have reported that in pea, bean, tomato, pepper, sweet corn, summer squash, cucumber, lettuce and cabbage plants when treated with GA at 10–20 mg/plant the leaves become broader or elongated. Similarly, it has been reported from Australia that gibberellin applied at the rate of one to four ounces per acre increased the leaf growth and dry matter yields of the first cutting of herbage but did not appreciably increase the yield for the whole year. Due to the expansion of the leaves by gibberellin application, the photosynthetic area is increased which subsequently heightens the total harvest of the crop.

Breaking up Dormancy of Plants and Seeds. Some plants cease their growth in the fall and do not resume it until a definite cold treatment is provided. But there are reports which state that spraying with gibberellins fulfills the cold requirement and helps plants to resume their growth.

Paterson (1957) reported that the dormant potato tubers can be made to sprout by soaking in an aqueous solution of GA at 25 ppm for 1½ hours. Lippert *et al.* (1958) reported that such treatment was effective even when applied to the parent plant before harvest. Similarly, grass can be induced to sprout during cold periods, during spring or fall, when normally no growth would occur (Leben and Barton, 1957).

Many seeds require a period of 'after ripening' or cold treatment, or exposure to light, or some other factors or combination of factors before they will germinate. These requirements have been eliminated in certain cases by the action of gibberellin, which annuls the light requirement of lettuce and tobacco seeds as reported by Kahn *et al.* (1957) and Ogawara and Ono (1957). Gray (1958) reported that Gibberellin spray annuls the cold requirement of peach seeds and according to Kribben (1957) it also fulfills the light and stratification requirements of arabidopsis seeds and induce them to germinate. Frankland and Wareing (1960) reported that GA at 0.1 mg/l had induced hypocotyl elongation in lettuce seeds under dark conditions. Blumenthal *et al.* (1960) stated that endogenous growth substances like coumarin have been found in dry lettuce seeds in quantities greater than other mature seeds, but below the levels found in immature seeds but he failed to establish any relationship with GA activity. Hence, this development has immediate horticultural utility as it eliminates the waiting period between generation of plants.

Parthenocarpic fruit development in peach had been reported by application of GA (Crane *et al.*, 1960). Four concentrations of GA (25, 50, 100 and 150 ppm) and three of thiourea (2,500, 5,000 and 10,000 ppm) were tested for their influence on the germination of peach seeds. These treatments were given in combination with three chilling temperatures of 4°, 8° and 10°C and four stratification periods of 7, 14, 21 and 28 days. GA at 150 ppm resulted in higher percentage germination of peach seed as compared with its other concentrations. The medium level (5,000 ppm) of thiourea was more effective than either of the lower (2,500 ppm) or the higher level (10,000 ppm) in increasing the germination percentage of peach seeds (Singh *et al.*, 1966).

Germination of Seeds. Rao *et al.* (1963) soaked seeds of *Morus indica* in solutions of GA at 10, 25, 50 and 100 ppm for 24 hours after pre-soaking in water, and their germination was compared with that of seeds soaked in water alone. In all cases, the germination rate was accelerated, the germination percentage was increased and length of the seedlings after 12 days growth was greater. The optimum GA concentration was 50 ppm with which 94 per cent germination was obtained. Gray (1957) reported that the seeds of peas, sweet corn, bean, beet and tomato when coated with a GA-methyl cellulose (0.4, 0.2, 1.0 and 5.0 per cent) slunny, dried and planted, the seedlings come up faster and grow taller than seedlings from the untreated seeds. Undoubtedly this behaviour of gibberellin has got some practical implication in the field of horticulture.

Fruit Setting and Fruit Development. Hield *et al.* (1958) reported that in Beress lime 100 ppm GA increased the fruit set to maximum over control without any difference in fruit size, percentage of soluble solids and juice but in Eureka lemon and Washington Navel orange 1,000 ppm of GA increased the fruit set to maximum. Weaver (1958) reported that application of GA gave increased fruit set in Thompson seedless grapes. Berry size of Black Corinth grape was enlarged when clusters were dipped in solution of 5-500 ppm of GA. Krishnamurthi *et al.* (1959) reported that GA has got positive effect in increasing the fruit set in Pusa Seedless. Kononov (1960) reported that immersion of the inflorescences at the beginning of flowering for 20-30 seconds in 0.0025 per cent of GA solution in water improved the fruit set and increased the sugar content of grapes.

Rappaport (1956, 1957) reported the increased fruit set in tomato plants by gibberellin spray (1-500 ppm) but fruit sizes and development were unaffected. Liverman and Johnson (1957) reported that spraying the summer dormant fruits of tomato with gibberellins (25 ppm) five times on alternate days resulted in an appreciable number of enlarged fruits. But, according to Rappaport (1960) temperature has a pronounced effect on the enlargement of the tomato fruits from flowers either at the coolest (11°C) or warmest (23°C) night temperatures but it strikingly reduces fruit size at an optimal temperature (17°C). Bukovac and Wittwer (1957) have reported normal fruit development in carrot, beet, cabbage, etc. by 100-1,000 ppm gibberellin application.

Induction of Parthenocarpy. Crane (1958) obtained 96 to 100 per cent parthenocarpic fruit set in calymyrna fig with 1,000 ppm GA. Crane *et al.* (1960) reported that GA at 50, 250, 500 ppm induced parthenocarpy and higher set in case of peach.

Similarly, parthenocarpic development of vegetable crops such as tomato, brinjal and cucumbers have been reported by many workers. Wittwer and Bukovac (1957) reported the parthenocarpic fruit development in *Solanum melongena* L. Parthenocarpic fruit development in tomato by the application of gibberellin at 10^{-1} to 10^{-5} per cent in lanolin paste has been reported by Wittwer *et al.* (1957).

Sex Expression. Galun (1959) reported that GA at 1-100 ppm, applied to cucumber plants, induced a marked change towards maleness. According to Paterson and Anhder (1960), 2,000 ppm GA induced the formation of staminate flowers in gynaecious cucumber vines. Chaudhury and Phatak (1959) observed that spraying of 10 ppm GA induced marked reduction in the number of male flowers and increase in the number of female flowers was 106 : 1 in treated as compared to 323 : 1 in control.

Effect on Metabolism. Metabolism effects of the gibberellins have been sought since long past but no clear cut association with any metabolic pathway has yet been established. Analysis has, however, shown the greatest changes among carbohydrate constituents (Wittwer *et al.*, 1957).

Wittwer *et al.* (1958) concluded that by proper timing of GA treatment the photosynthesizing surface could be increased and might result in the accumulation of greater quantities of sucrose in sugar-producing plants like sugar beets and sugarcane. Another obvious effect reported is the reduction of chlorophyll content accompanying the chlorosis caused by higher dosages of gibberellins.

Burk and Tro (1958) observed increased nicotine after spraying with gibberellin and hence they assumed that it was an indicative of some fundamental dislocation of nitrogen metabolism which was not reflected in the nitrogen fraction determination.

Coulombe and Paquin (1959) have reported that tomato foliage, entirely or partially sprayed with GA solution, showed 1 or 2 hours later a rapid increase in respiration, photosynthesis and transpiration.

Root Growth. Various experiments have suggested that gibberellins have no effect on root growth. Experiments on rooting of cuttings are most conclusive and clearly show that not only root initiation is inhibited by gibberellin but that the stimulation of rooting caused by auxin is counteracted (Kato, 1958)

However, growth of roots of some genotypes of maize is reported to have been stimulated by GA (Whaley and Kephart, 1957). So the question is still confusing, and needs further investigation.

Hyponasty of Leaves. Several workers have observed that the first indication of the effectiveness of application of gibberellin is a change in the angles of the leaves in relation to the stem. It is reported by Lert (1959) that treated chrysanthemums hold their leaves more errect.

Cell Division. It was thought earlier that gibberellin does not take part in cell division but Sachs and Lang (1957) have observed an increase in cell division in less than 24 hours in *Hyoscyamus* induced by gibberellin to form a flower stalk. Chandler (1957) has also reported that the anthers of *Allium cepa*, treated with GA, divide rapidly as compared to control.

INTER-RELATIONS BETWEEN AUXINS AND GIBBERELLINS

The experiment conducted by Kuse (1958) on sweet potato petioles indicated that gibberellin did not promote petiole elongation in the absence of auxin but was strongly stimulatory in the presence of endogenous or applied auxin. Studies of Brian and Hamming (1958) and Radley (1958) on pea stem sections showed that GA was dependent on its action of IAA. However, auxins bring about effects even in the absence of GA. It could then be regarded that GA behaved more as an auxin adjuvant than an auxin. But in case of root initiation, GA had no effect, which showed that mechanism of GA action was more complex and interactions of GA and auxins were more complicated.

Brian (1959) had put a hypothesis that GA removed the effect of inhibiting system and thus released more potentiality of endogenous auxins.

Thus it may be concluded that growth regulation is dependent upon the balance of GA, auxins and growth inhibitory system. Though there are some similarities in the action of gibberellins and auxins on plants, they were distinctly different in many respects which are summarized below :

SIMILARITIES AND DIFFERENCES IN ACTION ON PLANTS BETWEEN AUXINS AND GIBBERELLINS

Plant response	*Gibberellin*	*Auxin*
Transport polar	No	Yes
Promote root initiation	No	Yes
Inhibit lateral buds	No	Yes
Delay in leaf abscission	No	Yes

Overcoming the genetic and physiological dwarfism	Yes	No
Promote seed germination and breaking of dormancy	Yes	No
Induction of flowering of long-day plants and biennial plants	Yes	No
Promote elongation of cells	Yes	No
Induction of parthenocarpy in certain unfertilized ovaries	Yes	No

Application of gibberellins to seeds, soil or growing plants for increasing crop yields, other than fruits, has been generally disappointing. In comprehensive field trial by Morgan and Mees (1958) with wheat, potatoes, turnips, carrots, peas, runner beans, lettuce, celery, black currants, kale and maize, treatment with gibberellic acid failed to increase yield. Grass is the only crop so far reported to show yield increase from application of gibberellin, but this treatment had no advantage over fertilizer application for increasing the growth except in spring or autumn when the action of fertilizer was slow (Wittwer and Bukovac, 1958). So the main application of gibberellins is still in the field of horticulture.

Role in Pomology

Apple. Golden delicious apple trees treated with GA formed more flower buds than control, whereas on percentage basis, the flower buds were lower than in control. It may be concluded that the enhancement of the growth of the shoots (both main and lateral shoots) by GA treatment corresponds to a relative decrease in the capacity of the buds to form flowers (Marcelle and Sironval, 1963).

Peach and Pear. GA at 80 and 1,000 ppm applied in late August and September were effective in increasing bud hardiness of Elberta peach. Application in November reduced hardiness. Blossoming was delayed up to seven days in appearance (Proebsting and Mills, 1964). Griggs and Iwakari (1961) observed that application of GA at 10-50 ppm reduced fruit abscission in Bartlett pear.

Strawberry. The plants of Pusa Dwarf Early strawberry plants were sprayed with aqueous solutions of potassium salt of GA (5 and 10 ppm). GA sprays increased the height of plants, length of peduncle and fruit bud formation significantly over rest of the treatments including control. GA (5 and 10 ppm) increased the total yield per plant by 48 and 62 per cent respectively over control without adversely affecting the fruit quality (Singh and Randhawa, 1959). In the second trial, Singh *et al.* (1960) applied GA at higher concentrations (25, 50, 75 and 100 ppm) 26 days after transplanting plants. Flower formation was hastened by 25 to 31 days and crops matured earlier by 19 to 23 days when sprayed with GA as compared to control. The duration of harvest was also prolonged to 34 to 38 days against 22 days in control. GA sprays increased both early and total yields significantly. These studies indicate the practical value of GA at 75 ppm for extending the period of availability and for improving early and total yields in Pusa Dwarf Early strawberry. Turner (1963) found that all treatments of GA (12.5, 25, 50 and 75 ppm) to strawberry plants accelerated flowering. Ripening was accelerated by several days particularly and higher concentrations of GA, and the effect was greater with repeated applications. Total yields were not significantly improved but the number of berries increased with increasing concentrations. At the double and triple applications of 50 and 75 ppm, the fruits were elongated and substandard.

Blueberry. GA at 20 ppm resulted in parthenocarpic fruit set in the lowbush blueberry (*Vaccinium angustifolium* Ait.). The chemical must contact the flower directly from shortly before the blossom opens to petal drop. Field trials have not demonstrated the effectiveness of this compound in economic fruit production (Collins *et al.*, 1966).

Citrus. Randhawa and Singh (1959) reported that application of GA at 100 ppm showed manimum increase of growth, length and fresh weight of citrus seedlings root-stock.

Randhawa *et al.*(1959) further reported that GA (10 ppm) increased fruit set and reduced the fruit drop significantly in sweet lime. The number of fruit per tree increased as a result of GA (10 ppm) sprays to an extent of 111.11 per cent over control. Soost and Burnett (1961) reported that application of potassium gibberellate at 100-500 ppm improved fruit set but resulted in decreased yield due to limited cross-pollination in Clementine mandarin. Randhawa and Sharma (1962) reported that fruit set was the highest in Jaffa orange (68.47 per cent) by GA at 100 ppm, and in Pineapple orange (63.49 per cent) by GA 75 ppm. GA (50 ppm) in Jaffa and GA (75 ppm) in Pineapple significantly reduced the 'June drop' over control.

Dhuria and Randhawa (1963) found that GA at 25, 50, and 100 ppm increased the germination of sweet lime pollen but decreased it in grapefruit as the GA concentration was increased. Pollen tube growth increased in both the species with GA treatment and was greatest at 100 ppm. Thomas *et al.* (1963) found that each application of

GA was followed by an immediate spurt of activity reflected by stem elongation within a month of treatment. Increase in stem diameter was more or less on the pattern of the increase in stem height. There was an increase in the number of leaves following GA treatment, the effect being more pronounced at higher concentrations. The shape and size of leaves were not influenced. GA at 100 ppm resulted in injury of apical meristematic regions of pummelo seedlings.

Randhawa *et al.* (1964) found that GA treatments (25 to 1,000 ppm) induced parthenocarpic fruit set in grapefruit and mandarin oranges. The percentage of fruit set and fruits harvested in grapefruit increased with the concentrations of GA, whereas in mandarin the fruits dropped before maturity. Acidity and total reducing sugars were generally increased in parthenocarpic grapefruits. However, GA at all concentrations increased the fruit size of grapefruit appreciably. Randhawa and Dhuria (1965) further observed that GA (500, 750 and 1,000 ppm) exhibited significant increase in fruit set in sweet lime. Coggins *et al.* (1963) noted that GA (5 to 20 ppm) reduced the susceptibility of Navel Orange rinds to a physiological disorder termed ring staining. This condition is associated with mechanical abraision of the rind and is generally more serious if the crop is harvested late in the season. The results indicated that a minimum of about one month must elapse between application and reduction of susceptibility. The material should be applied after the marketable colour has developed. The resistance of the Navel Orange rind to rupture by a small penetration tip was evaluated for an 8-month period that began about 2½ months before the start of harvest and ended one month after the season. Treatments of KGA applied to green-coloured fruits in October or to orange coloured fruits (January–March) caused the rinds to be more resistant to puncture. The treatment on January 4 and February 21 caused the fruits to become more resistant than they were at treatment time, while the two others treatments resulted in a much slower decrease in resistance.

Elastic and plastic properties of the rind changed with time and were also influenced by KGA. When Navel oranges age on the tree, the rind surface may become plastic and sticky. This condition was markedly reduced or eliminated by KGA (Coggins and Lewis, 1965).

Grapes. Stewart *et al.* (1957) reported that in Thompson Seedless grapes a single application of either 10 or 100 ppm of GA resulted in fruit bunches 50 per cent larger than normal. Increase in sugar content and decrease in acid content were observed in treated berries. Weaver and McCune (1958) also observed an increase in berry size in Black Corinth variety when sprayed with 5 ppm GA. Thompson Seedless vines gave longer clusters with 10–50 ppm of GA applied at prebloom stage. Krishnamurthi *et al.* (1959) applied aqueous solutions of GA at 10, 25 and 50 ppm to flower clusters of Pusa Seedless grape. The fruit set was increased significantly at lower concentration. Applications at higher concentration (50 ppm) resulted in thinning of flowers and reduction of fruit set, but produced highest average weights of both the bunch and the berry with increase of 223.13 and 139.43 per cent, respectively, over the control. The treatments, in general, tended to elongate the shape of the berry and did not effect adversely the high quality of the Pusa Seedless grape. Manankov (1960) observed more parthenocarpic development of the berries with the application of 10 mg/g GA. Early ripening of the berries of Chanch and Nimrang by 10 to 20 days was observed by treating their flowers twice with GA. Venkataratnam (1961) reported that pre-anthesis application of GA at 40 ppm produced significant increase in the size of bunch and berry of Anab-e-Shahi grape. Application of GA to seedless varieties of *V. labrusca* L. also increased berry and cluster size in Concord and Interlaken (Shaullis, 1959). But, he found very little increase in number and weight of berries of seeded varieties. Berries of seeded variety Delaware matured 15–20 days earlier than untreated berries when the clusters were sprayed 10–20 days before full bloom. All the berries in the treated clusters were seedless and larger than the untreated seeded berries.

Weaver (1961) stated that the response of grapes to exogenous gibberellins will essentially occur naturally under suitable environmental conditions. Endogenous gibberellins have been found in the berries of seedless grapes. Gibberellins can act as a pollenicide when applied at pre-blossom bloom stage. Commercial uses for gibberellins on grape include elongation of cluster part to decrease rotting, enlargement of berries and increasing berry set.

Hartmair and Hobi (1963) noted that spraying vine cuttings with GA always resulted in shoot elongation, but considerable varietal variation was noted. GA inhibited root growth except in the case of Veltliner Gruu, on which four sprays with 100 ppm GA promoted root growth. Grafts of Rheinriesling on Kober 5BB treated with 0.04 per cent Gibboc showed better callus formation than the controls. Treatment of inflorescence buds resulted in earlier flowering and increased fruit drop in most varieties. Veltliner Rot, however, responded differently from other seeded varieties, being less sensitive to GA and early treatment of the inflorescence, increasing the size of the berries and reducing fruit drop. Dipping Delaware grape clusters in 100 ppm GA at pre-bloom and again at post-bloom resulted in an average of 88 and

95 per cent seedless berries in 1963 and 1964 respectively, and advanced maturity by about 28 days. The seedless berries enlarged to nearly normal size. Cluster sprayed pre- and post-bloom in 1964 produced 94.7 per cent seedless berries. Dipping at pre-bloom only induced seedlessness and advanced maturity, but the berries remained small. Dipping at post-bloom only resulted in 10 and 46 per cent seedless berries in 1963 and 1964 respectively, GA treatments tended to lower the sugar-acid ratio of seedless berries (Clore, 1965).

Phalsa. Sprays of GA (10 ppm) markedly increased fruit set in *phalsa.* The fruit set, however, decreased with the increase in concentration of GA (Randhawa *et al.*, 1959). Rao and Rao (1963) applied GA at several concentrations (150–2,000 ppm) to flowering shoots of *phalsa* as aqueous spray. GA (300 ppm) increased fruit set by 34.0 and 15.6 per cent over control. Treatment with 500 ppm increased fruit set by 23.6 per cent and bud stage and 11.7 per cent at flowering stage. GA at 600 ppm produced 33.3 per cent of seedless fruits. GA applied at 1,000 and 2,000 ppm were effective in producing parthenocarpic fruits.

Fig. Parthenocarpic fruit set was observed by Crane (1958) in Calymyrna fig after spraying with GA at 1,000 ppm. Crane and Grossi (1960) also found that fruit maturity was hastened in Mission fig by 12–25 days when sprayed with 20-28 ppm GA.

Role in Olericulture

Zauralov (1963) reported that young plants of maize, cucumber and melon sprayed with gibberellin each day for a week and subjected to 8 hours chilling at 3° to 6°C for three days did not greatly affect the stimulatory action of gibberellin on the growth of maize, but to some extent counteracted the stimulatory action of gibberellin on the growth of cucumber plants. Gibberellin treatment alone had little effect on melons, but cooling at first retarded the growth of gibberellin-treated plants more than the control. In all the cases treatment with gibberellin followed by cooling delayed flowering.

Celery. Wittwer and Bukovac (1957) observed that 3–15 g of foliar spray of GA per acre applied at 2–4 weeks before harvest was best in increasing yield, greater stalk, weight and length of the celery. Bukovac *et al.* (1960) also reported that 50 and 100 ppm GA, applied as pre-harvest foliar spray, increased petiole length and fresh weight of marketable stalks but certain bad effects such as twisting of petioles and rapid breakdown in storage were also observed.

Cabbage. Chhonkar and Singh (1963) observed that GA at 5 and 10 ppm promoted quick recovery of seedlings. Larger number of inner leaves in heads were observed. There was early and uniform harvesting of heads 16 days earlier than the control. The application of GA failed to increase the root system but improved the cooking quality and palatability values. Two applications of GA at 5 ppm proved to be the best treatment for maximum increase in yield and quality of heads.

Radish. Wittwer and Bukovac (1957) stated that in radish 1,000 ppm GA resulted in seed stalk formation, flowering and earlier seed maturity.

Lettuce. Harrington (1960) used the seed stalk promoting tendency of GA to prevent heading, induce bolting and increase seed yield of high heading lettuce. He observed that when GA was sprayed at 3–10 ppm on lettuce plants at 4 to 8 leaf stage of growth, the crop matured about two weeks earlier and the yield was significantly higher than the control.

Spinach. When spinach plants were transferred from short days to continuous light a large temporary increase in gibberellin content occurred after one day. Several days after transfer the gibberellin content was less than that of plants in short days. It was suggested that the increase in gibberellin stimulated cell division and that subsequently the turnover of gibberellin was greatly increased (Radley, 1963).

Tomato. Bukovac *et al.* (1957) reported that early flowering in tomato, induced by gibberellin at 1 to 100 ppm resulted in early fruiting and increased early yields.

Sweet Corn. The foliar spray of 10–250 ppm of GA on sweet corn resulted in frequent male sterility (Bukovac *et al.*, 1957).

Peas. In light grown Alaska peas, GA_5 was found half as active as GA_1 in promoting stem elongation, but both gibberellins were equally effective when applied to etiolated peas. It was concluded that illumination lowers the sensitivity of the plants to the GA_5-like fraction to GA_5, but does not affect sensitivity to the GA_1-like fraction to GA_1 (Kenede and Lang, 1964).

Carrot. A number of GA applications to the leaves of young plants of the carrot variety Rogue Longue geante de Flakee promoted growth of the leaves and stems but inhibited that of the roots. B-carotene accumulation in the roots was inhibited, the lutein content remained unaffected, but there was an accumulation of a product or products having strong absorption bans in the U.V. region with a maximum near 330 mμ (Michel-Wolwertz and Sironval, 1963).

French bean. GA increased primary leaf growth only transiently when applied to epicotyls of intact plants, whereas when applied to the primary leaves it continued to increase their growth and produced larger mature leaves than control. GA applied to the epicotyls increased internode extension twice as much as GA applied to primary leaves. Removing the apical growing point shortened hypocotyls but not epicotyls (Wheeler and Humphries, 1964).

Potato. In potato, GA is used to break dormancy of seed tubers. Timm and Rappaport (1960) tried GA to increase tuber production but the result was not encouraging.

Role in Floriculture

The striking effects of gibberellin in ornamental crops may be classified as (*a*) replacement of long-day and low temperature requirements, (*b*) early flowering and acceleration of flowers, and (*c*) increasing size of flowers.

Wittwer and Bukovac (1957) have reported that long-day requirement of some of the annuals like dill, endevice, and petunia and low temperature requirement of some biennials like pansy, stock, fox glove and English daisy, China aster and gerbera have been met by GA treatment.

Chrysanthemum. Harada and Nitsch (1959) reported that GA can induce early flowering in chrysanthemum. Lert (1959) stated that application of 10–500 ppm of GA resulted in improved shape of flowers and long flower stalks in chrysanthemum.

Azalea. The use of photoperiod and GA treatments (0, 100 and 1,000 ppm) in an effort to reduce the breeding cycle of azalea by increasing the growth response was unsuccessful. Vegetative growth of azalea seedling and cutting was increased by using extended photoperiod treatments and applying GA as an aqueous spray (Sink and Walker, 1964).

Geranium. Lindstrom and Wittwer (1957) observed that in geranium 10 ppm of GA resulted in increased florescence and flower size. Biswas and Roger (1963) noted increase in flower size with increased concentrations of GA used. Maximum size was obtained with 100 ppm GA, the higher concentration used. Higher concentrations caused lodging of the inflorescence in Irene and Penny. GA at 5 ppm would appear satisfactory for commercial use. The increased inflorescence size was due mainly to increased length of petal and pedicels. The flowers which developed from seeds dipped into solutions were more desirable than those from sprayed plants.

Camellia. A convenient method of treating camellia flower buds with GA is to break out the adjacent growth bud and fill the remaining cup with GA solution. Preliminary trials gave very variable results, but there was a tendency for treatment to induce earlier flowering. GA improved the size and quality of the flowers only when the treatment was applied to suitable buds. The terminal shoots developing from buds treated with GA made weak growth. When these terminals were pruned off, growth was normal. Treatment of the buds on one plant with GA resulted in heavy defoliation, but after severe pruning vigorous new growth developed (Racoff, 1963).

Lilac. The leaves of lilac were found to develop normally, but the growth of axillary buds depressed and no real leaf or primordia initiated as a result of GA (0.5 per cent) application to the lower surfaces of lilac leaves. The shoot became thicker. Phyllotaxy was abnormal in shoots developing from these late developing buds. However, the shooting of small basal 'Sleeping buds', which occurred when the shoot was severed above them accentuated by the application of GA (1) below tips. It was suggested that GA lowered the correlative inhibiting effects of the leaves on the bud scale (Dostal, 1964).

Methiola incane. Plants of the varieties Lilac, Lavender, Ruby Red, Ball Supreme and Pecific White sprayed with GA (100 ppm) three times at weekly intervals were taller and had fewer leaves than the untreated plants. The weights of treated plants that did flower were less than those of controls (Biswas and Rogers, 1963).

China rose. Flowers including the subtending foliage of "China rose" were treated with GA (50-600 ppm). The percentage of fruit set increased with the concentration of GA. As the concentration increased from 200 to 600 ppm, there was a gradual increase in average weight and length of the fruit. GA at 400 to 600 ppm increased fruit set to 80 per cent and 96 per cent respectively, and all the fruits were retained till harvest. The fruits were found to be seedless. It was established that GA applications could be successfully used for production of fruits in genetically sterile plants (Rao and Rao, 1963).

REFERENCES

CHAPTER I

Aguirre, J.T. Marino, E.F. and Fernandez-cano, L.H. 1951. Accion de las hetero auxinas Yotrds Tratamientos de las estacas de vid para favorencer su enraiza miento. *Bon. Inst. Invest. agron. Madrid* **11** : 315-69.

———— 1953. Neuvos ensayos sobre la accion de hetero auxins enla multiplication de la vid por estaca. *ibid.* **13** (28) : 100-37.

Amlong, H.V. and Naundrof, G. 1937. Uber einige praktische Anwendungen der Pflanzlichen steckungswuchsstoffe. *Forschungsdients.* **4** : 417-28 (c.f. *C.A.B. Tech. Com.* No. 20).

Anliker, J. and Kobel, F. 1945. Wuchsstoffversuchemit Rebveredlungen. *Landw. Jahrb. Schweiz.* **59** : 203-48.

Baile, J.B. and Halam, F.F. 1938. The use of heteroauxin in rooting of sub-tropicals. *Proc. Am. Soc. hort. Sci.*

Baranova, E.A. 1946. Effect of heteroauxin upon rooting and anatomical structure of green cuttings of vine (*Vitis amurensis*). *C.R. Akad. Sci. U.R.S.S.* **54** : 729-31.

Beal, J.M. 1946. Reactions of decapilated beans to certain phenoxy compounds. *Bot. Gaz.* **108** : 166-86.

———— 1951. *Histological Responses to Growth Substances.* In Skoog (Ed.), *Plant Growth Substances.* Univ. of Wis. Press, Madison.

Bhattacharya, S. 1959. *Propagation Studies in Grape, Citrus and Guava with the Aid of Plant Growth Regulators.* Thesis submitted in partial fulfilment for the associateship of the I.A.R.I., New Delhi.

Bove, J. 1957. Le bouturage des citrus. *Fruits d' Outre Mer.* **12** : 25359.

Brase, K.D. 1938. Synthetic growth substances in the rooting of soft wood cuttings of deciduous fruits. *Proc. Am. Soc. hort. Sci.* **38** : 431-37.

Cailahjan, M.H. and Nekrasova, T.V. 1958. The effect of growth substances on overcoming polarity in lemon cuttings (Russian). *Dokl. Akcd. Nauk SSSR* **119** : 826-29.

Chadwick, L.C. 1931. Experimental work in plant propagation in Ohio University. *Proc. Annu. meet. Am. Pl. Prop. Assoc.*

———— 1937. Effect of synthetic growth substances on the rooting of cuttings of woody ornamental plants. *Ohio State. Univ. Nursery Notes Dep. Hort.* 7 (1) : 1-11.

Choudhary, B., and Singh, S.N. 1960. Seed treatment with plant regulators and their effect on growth and yield of tomato (*L. esculentum*). *Indian J. Hort.* **17** : 48-51.

Clarence Gaideon, A. and Carasimha Rao, V.L. 1956. Actions of auxins on germination of groundnut. *Sci. & Cult.* **22** (11) : 632.

Commoner, B. and Thimann, K.V. 1941. On the relation between growth and respiration in the *Avena* coleoptile. *J. genet. Physiol.* : 279-96.

Cooper, W.C. 1935. Hormones in relation to root formation on stem cuttings. *Pl. Physiol.* **10** : 789-94.

———— 1936. Transport of root forming hormone in woody cuttings. *ibid.* **11** : 779-93.

———— 1940. Rooting citrus cuttings with synthetic growth substances. *Proc. Fla Stn Hort. Soc.* : 174-77.

———— 1944. The concentrated solution dip method of treating cuttings with growth substances. *Proc. Am. Soc. hort. Sci.* **44** : 533-41.

———— and Knowlton, K.R. 1940. The effect of synthetic growth substances on rooting of sub-tropical fruit plants. *ibid.* **37** : 1093-98.

Cosmo, 1952. Ulteriori indagini sullimpiego di sostanze rizogene nella preparazione di carbatellae di vite innestate e franche. *Ann. Sper. agrar.* **6** : 591-613.

Crane, J.C. and Mallack, T.S 1952. Varietal root and top regeneration in fig cuttings as influenced by the application of indolebutyric acid. *Pl. Physiol.* **27** : 309-19.

Das, D.N., Singh, B., Parida, G.N. and Singh, R.P. 1959. Interplay of factors influencing the performance of sweet and *kagzi* lime cuttings. *B.V.J. Agric. Sci. Res.* **1** (1) : 16-22.

Deshpande, B.R. and Kulkarni, V.G. 1962. Use of 2,4-D for the propagation of Rosa Edward (*R. borboniana* DESP) by stem cuttings. *Sci. & Cult.* **28** (3) : 139.

Dikshit, N.N. 1953. Studies in the propagation of plum, horti. variety Kelsey (*Prunus sadicina* Lindl.) by stem cuttings. *ibid.* **18** : 496.

———— 1956. Propagation of *kagzi* lime by cuttings. *ibid.* **21** : 336.

Doak, B.W. 1939. The use of hormones as an aid to the propagation of plants. *N. J. Sci. & Technol.* **20** : 269A-80A.

Donoho, C.W. (Jr) and Walker, D.R. 1957. Effect of GA on breaking of rest period in Elberta peach. *Science* **126** : 1178-79.

Dostal, R. 1949. The importance of growth producing substances for slip-rooting of the goose berry and of the apple (Cox's Runette). *Shornik Cerkoslov. Akad. Temerdekske.* **17** : 2-7.

Dragas, M. and Avramov, L. 1953. Primena sintetiokih fitohormona na vegetativno razmnozavnje podloga vinove loze. II. *Zemlj. V. Bilj., Belgrade* **2** : 87-108.

Erickson, L C. and Bitters, W.P 1953. Effect of various plant regulators on rooting of cuttings of citrus and related species. *Proc. Am. Soc. hort. Sci.* **61** : 84-88.

———— and De Bach, P. 1953. Rooting lemon cuttings with fruits attached. *Science* **117** : 102-3.

Evenari, N. and Kaonis, E. 1933. The effect of heteroauxin on root formation by cuttings and on grafting. *Palest. J. Bot. Jerusalem Ser.* **1** : 13-26.

Fillippenko, I.M. 1960. Effects of GA on the growth, development and fruiting of vines (Russian). *Agrobiologiya* **5** : 770-73.

Fogle, H.W. and McCroy, C.W 1960 Effects of cracking, after-ripening and gibberellin on germination of Lambert cherry seeds. *Proc. Am. Soc. hort. Sci.* **76** : 134-38.

Frankland, B. 1961. Effect of GA, Kinetin and other substances on seed dormancy *Nature, Lond.* **192** : 678-79.

Garner, R.J. and Hatcher, E.S.J. 1955. The influence of source and growth substance on the behaviour of apple and plum cuttings. *J. hort. Sci.* : 116-28.

Gocolasvili, M.M and Maximo, N.A. 1937 Effect of heteroauxins in the rootage of cuttings from sub-tropical wood. *C.r. Acad Sci. U.R.S S.* **17** : 51-4.

Godara, P.S 1960. *Propagation Studies in Mango* (Mangifera indica *L.*), *Guava* (Psidium guajava L) *and Phalsa* (Grewia asiatica) Thesis submitted in partial fulfilment for the degree of Master of Science in Horticulture, I.A.R.I., New Delhi.

Grace, N H 1937. Physiological curve of response to phytohormone by seeds, growing plant cuttings and lower plant forms. *Canad. J. Res.* **15** : 538-46.

——— 1939. Physiological activity of a series of naphthyl acids *ibid* **17** : 247-55.

——— 1940 Responses of plant cuttings to treatment with naphthyl acids and their potassium salts in talc. carrier. *ibid.* **18** : 457-68.

Hass, A.R C and Brusca, J.N. 1954. 2,4-D treatment of citrus. *Beed. Calif. Agric.* 8(2) : 8, 12.

Handaw, N. 1940. The effect of heteroauxins on the germination of some seeds. *Palest. J Bot. Jeruselum Ser.* **1** : 409-12.

Hartman, H.J. and Hansen, C.H. 1958 Effect of season of collecting indolebutyric acid and pre-planting storage treatments on the rooting of Marianna plum, Peach and Quince hard-wood cuttings. *Proc. Am. Soc. hort. Sci.* **71** : 57, 66.

Hayashi, T 1940. Biochemical studies on "Bakanae" fungus of rice. Part IV. Effect of gibberellin on the activity of amylase in germinated cereal grains. *J. agric. Chem Soc. Japan* 16(6) : 531-38.

Heymann-Herschberg, L. 1949. The effect of synthetic growth substances on the rooting of grapevine cuttings. *Palest. J. Bot. Jeruselum Ser.* **7** : 113-23.

Hildreth, A.C. and Mitchell, J.W. 1939. Spraying is a new method of applying root-promoting substances. *Flor. Rev. May* **25** : 14.

Hitchcock, A.E. and Zimmerman, P.W. 1936. Effect of growth substances on the rooting response of cuttings. *Contr. Boyce Thompson Inst. Pl. Res.* **8** : 63-79.

——— 1938. The use of green tissue test objects for determining the physiological activity of growth substances. *ibid.* 9.

——— 1939. Comparative activity of root-inducing substances and methods for treating cuttings. *ibid.* **10** : 461-80.

——— 1940. Effects obtained with mixtures of root-inducing and other sub stances. *ibid.* **11** : 143-60.

Hsuch, Y.L. and Lou, C.H. 1947. Effect of 2,4-D on seed germination and respiration. *Science* **105** : 283-85.

Inforzato, R. 1950. O emprego de hormonios no enraizamento de estacas do amorera. *Bragentia* **10** : 38587.

Jauhari, O.S. and Jit, A. 1960. Air layering in loquat (*Eriobotrya japonica* Lindl.). var. Pale Yellow, with the aid of growth regulators. *Sci. & Cult.* **25** : 592.

———, and Rahman, S.F. 1959. Further investigations on rooting in cutting of sweet lime (*Citrus limettioides* Tanaka). *ibid.* **24** : 432-34.

Kirpatrick, H. 1939. Latest Information concerning root-inducing substances and improved method of using them. *South Fla Nurseryman* **47** : 4.

Kondo, I.N. 1948. Inducing root development in grape vine cuttings with growth substances (Russian). *Dokl. Akad. Nauk SSSR* **60** : 685-88.

Kordes, H. 1938. Bedeutung der Wuchsstoffe fur die vegetative vermehrungder Rebe. *Garden bawiorss* **11** : 545-54.

——— 1943. Bedeutung der Wuchsstoffe fur die vegetative vermehrungder Rebe. *ibid.* **11** : 545-54.

Kulkarni, V.G. and Deshpande, B.R. 1964. Effect of 2,4-D on germination of coconut. *Sci. & Cult.* **30** (9) : 452.

Leopold, A.C. 1955. *Auxins and Plant Growth.* Univ. of California Press, Berkeley.

Markin, M.I. 1953. The effect of growth stimulators on cuttings and transplants. *Vinodelie i Vinogradarstvo* 1953 (4), pp. 40-44.

Martinez-Zaporta, M. 1949. Experincas correspondentas alarco 1948 sobre enraiza-miento de portainjertoas usuales con sangre de berlandven. *Boln Inst. Investnac. agron. Madrid* 9 : 1-47.

Marques de Almeida, C.R. 1938. Nota previa sobres emprego do acido B-indolylacetico no enraizamento da estacas da laranjeira azeda. *Boln. Soc. broteriana* **13** (Second Se.) : 117-21.

Misic, P.D. and Pavicevic, B.M. 1954. Vticaj sintetickog fitohormona Kalijumove soil alfa-naftalinsircetne na oziljavanji reznica lincina (*Citrus lemon* Burm.). *Arh. Poljopr. Nauke Teh* 7 (17) : 85-95.

Mohring, H.K. 1943. Zur Frage der ver mehrung unserer obstorten durch Wurzebxhnittlinge. *Otsch. Obstb.* **58** : 28-33.

Moretti, A. 1954. Le eterozuxine nella moltiplicazione del gelso. *Riv. Foultic.* **16** : 1-17.

Muller-Stoll, W.R. 1938. B-indoleacetic acid as an aid to callusing of stock and scion in vines. *Angew. Bot.* **20** : 218-38.

——— 1950. Wuchsstoffversuche mit Reben. II. Teil. Reaktions weise von samen, Keimeingen und nichtoholzigen organen der weinrebe auf Kunstliche Wuchsstoffgaben. *Zuchter* **20** : 213-26.

Mullner, L. 1952. Wuchsstoffversuche bei der Rebenveredling and stecklings ver mehrung. *Mitt. Klostemen-burg* **2** : 146-53.

Muznik, T.J. 1948. Vitamin B_1V_6. Organic matter for plant growth. *Proc. Am. Soc. hort. Sci.* **38** : 715-7.

Naundrof, G. and Terreros, J.M. 1952. Contribution alenraizaniento de estracas de *Citrus limon. Not. agron. Palmira* **5** : 43-7.

Pearse, H.L. and Garner, R.J. 1937. A note on the use of alpha naphthalene acetic acid for rooting cuttings of fruit tree stocks. *J. Pamol.* **15** : 248-51.

Pieri, G. 1959. Effeti dellacido gibberellico sulla vite. (The effects of GA on vines). *Riv. Vitic. Enol.* **12** : 409-18.

Pillay, D.T.N. and Edgerton, L.J. 1965. Relationship of growth substances to rest period and germination in Mazzard cherry seeds. *Proc. Am. Soc. hort. Sci.* **86** : 108-14.

Randhawa, G.S. and Thompson, R.C. 1948. Effect of hormone sprays on yield and snap beans. *ibid* **52** : 449-52.

Randhawa, G S. and Negi, S.S. 1964 Preliminary studies on seed germination and subsequent seedling growth in grape. *Indian J. Hort.* **21** (3&4) : 186-96.

Rao, L.S.P., Rao, T.P. and Narayanan, E.S. 1963. Response of mulberry seeds to gibberellic acid treatment. *Curr. Sci.* **32** : 348-49.

Rice, E.L. 1948. Absorption and translocation of ammonium 2,4-D by bean plants. *Bot. Gaz.* **109** : 301-14.

Rodriguez, Lopez, M. 1957. El problema de la rizogene sis en vitis de dificil enraizamiento. *Farmacognosia* **17** : 289-376.

Sebanek, J. 1955. On the stimulation of vegetables with growth stimulators. *Acta Univ. Agric. Silvie, Burno.* Ser. A (1) : 9-18 (c f. *C.A.B. Hort. Abstrr.* 3908, 1958).

Sen Gupta, J.C., and Chattopadhya, S.K. 1954. Hormones and rooting in intact plants and cuttings. *Curr. Sci.* **23** : 294-95.

Singh, K.K., Bakshi, J.C. and Sucha Singh 1960. Effect of callusing and seradix treatments on rooting of sweet lime cuttings. *Indian J. Hort.* **17** : 193-97.

Singh, K. Kirpal, Nijjar, G.S. and Sinha, T.N. 1966. Effect of GA and Thiourea on germination of peach seed. *J. Res.* 3 (2) : 146-51.

Singh, L.B. 1954. Propagation of mango by air-layering for rootstocks. *Proc. Am. Soc. hort. Sci.* 63 : 128-30.

Singh, R.P. 1959. Influence of indolebutyric acid and planting time on the performance of Kagzi lime (*Citrus aurantifolia* Swingle) softwood cuttings. *Indian J. Hort* **16** : 79-85.

——— 1960. *Studies in to the Effects of Source, Plant Regulator Treatment and Planting Environment on Citrus Cuttings.* Thesis submitted to Agra University for the Degree of Doctor of Philosophy in Horticulture, 1960.

Singh, S.N. 1950. Effect of some hormones on the rootage of *Psidium guajava* L. *Sci. & Cult.* **16** : 198-202.

——— 1954. Studies on the rootage of fruit plants in relation to hormones. IV. *Artocarpus heterophyllus* Lam. *ibid.* **20** : 393-95.

———, and **Sharma, M K.** 1954. Studies on the effects of some hormones on the rootage of *E. japonica* Lindl. var. Golden Yellow. *ibid.* **16** : 198-202.

Singh, S.N. 1955. Studies on rootage of fruit plants in relation to hormones. V. Citrus fruits. *ibid.* **21** : 206-8.

Sinha, A.C. 1942. Studies on the vegetative propagation of plum rootstocks by layering. *J. Pamol.* **20** : 1-11.

Skoog, F. 1944. Growth and organ formation in tobacco tissue culture. *Am. J. Bot.* **31** : 19-24.

Stoutemeyer, V.T. and O' Rourke, F.L. 1945. Rooting of cuttings from plants sprayed with growth-regulating substances. *Proc. Am. Soc. hort. Sci.* **46** : 407-11.

Thakurta, A.G. and Dutta, B K. 1941. Vegetative propagation of mango from gootees and cuttings by treatment with high concentration auxin. *Curr. Sci.* **10** : 297.

Tinker, M.A.H. 1936. Experiments with growth substances or hormones and the rooting of cuttings. *Jl R. hort. Soc.* **61** : 510-16.

——— 1938. Further experiments with growth substances and the rooting of cuttings. *ibid.* 63 : 210-29.

Toskie, V. and Avramov, L. 1952 Primena sintetickih fitohormona za vegetatinio razomnozavanje podloga vinove loze. *Zemlj. i. Bilj., Belgrade* 1 : 39-50.

Traub, H.P. 1938. Growth substances with particular reference to subtropical fruit plants. *Proc. Am. Soc. hort. Sci.* **35** : 438-42.

Treccani, C.P. 1950. Interaxione dell acido B-naftalena aceticoe micele nel radicamento di talee divite. *Riv. Fruttic.* **12** : 133-62.

Tukey, H.B. and Krishnamoorthy, S. 1948. Unpublished data.

Thomas, C.C. and Unwin, C.H. 1939. A further report on root forming substances used for propagation purposes. *Jl R. hort Soc.* **64.**

Van Overbeek, J., Olivo, D and de V'asquez, E.M.S. 1945. Rapid extraction method for free axuin and its application in geotropic reactions of bean and sugarcane. *Bot. Gaz.* **106** : 440-51.

———, **Gordon, S A. and Gregory, L.E.** 1946. An analysis of the function of the leaf in the process of root formation in cuttings. *Am. J. Bot.* **33** : 110-17.

Veldestra, H. 1943. Plant growth substances and their practical use. *Chem. Week. bl.* **40** : 158-66. 170-76.

Watkin, J.V. 1938. Response of certain tropical and subtropical plants to hormodin. *South Florist & Nurseryman* **45.**

Wittwer, S.H. and Bukovac, M.J. 1957. Gibberellin and higher plants VIII. Seed treatments for beans, peas and sweet corn. *Quart. Bull Mich. agric. Exp. Stn* **40** : (1) : 215-24.

Yorkes, G.E. 1938 Treat cuttings with Indole-butyric acid. *Am. Nurseryman* **45.**

Zimmerman, P.W. and Wilcoxon, F. 1935. Several chemical growth substances which cause initiation of roots and other responses in plants. *Contrb. Boyce Thomson Inst. Pl. Res.* **5** : 351-69.

CHAPTER II

Anonymous. *Annual Report of the Director, Delaware Agric. Exp. Stn for 1944-45,* pp. 43. Bull. 259.

Bakhinzen, H.L. Van de Sande 1953. Flowering and flowering hormones (one single scheme for both long-day and short-day plants) III. Photoperiodism in short-day plants. *Proc Kon ned Akad. Wetonsch Ser. C.* **56** : 164-83.

Batjer, L.P. and Uota, M 1951 Effect of 2,4,5-TP sprays on fruit set of pears and apples. *Proc. Am. Soc. hort. Sci.* **58** : 33-36.

Bukovac, M.J., Larsen, R.P and Bell, H K 1960 Effect of gibberellin on berry set and development of concord grapes. *Quart. Bull. Mich. agric Exp. Stn* **42** : 503-10.

Chattopadhya, S.K 1956. Results of further investigation on the effect of hormones on setting of fruits and induction of seedlessness. *Sci. & Cult.* **22** : 334-35.

Chhonkar, K.S, and Singh, S.N. 1959 Effect of NAA on growth, quality and yield of tomato (*L. esculentum* Mill) *Indian J. Hort* **16**(4) : 235-42.

Clark, H.E. and Kerns, K.R. 1943. Effects of growth regulating substances on parthenocarpic fruit. *Bot Gaz* **104** : 639-44.

Cooke, A.R. 1953. The relation of plant growth hormones to photoperiodism. *Diss. Abstr.* **13** : 641-42.

Coombe, B.G. 1953. Setting currants by spraying PCPA. *South Aust. J. Agric.* **57** : 107-10.

——— 1954. Last season's experience with PCPA on currants. *J. Dep. Agric. S. Aust.* **58** : 126-27.

Crane, J.C. and Blondeau, R. 1950. Further studies on the chemical induction of parthenocarpy in the calimyrna fig. *Pl. Physiol.* **25** : 158-60.

Davison, R.M. 1957. Trials of fruit setting sprays on glasshouse tomatoes. *N.Z.J. Sci. & Tech.* **38**(5) : A 544-47.

Dhawan, N.L. 1952. Studies on the effect of growth-regulating substances on fruitfulness in field grown tomatoes and the relation between seed formation and the production of growth regulating substances in the fruit. *Diss. Abstr.* **12** : 292.

Doughtty, C.C. 1959. Certain growth regulators on the fruit-set of cranberries (*Vaccinium macrocarpon*). *ibid* **20** : 837-38.

Emmert, E.M. 1956. You can grow early big tomatoes. *Am. Veg. Grow.* 4(2) : 11.

Erickson, L.C. 1951. Effects of 2,4-D on drop of navel oranges. *Proc. Am. Soc. hort. Sci.* **58** : 46-52.

——— and Haas, A.R.C. 1956. Size yield and quality of fruit produced by Eureka lemon trees sprayed with 2,4-D or 2,4,5-T. *Proc. Am. Soc. hort. Sci.* **67** : 210-21.

Fritzsche, R. 1950. Weitex Mitteiling Zu den versuchen sur Behebung der abwechsenden Tragbarkeit vei Apfelbanmen mit Hilfe van spritzmitteln (further communication on trial to control biennial bearing of apple by means of spray). *Schweiz. Z. Obst. V. Weint.* **60** : 207-11.

Gardner, F.E. 1950. Effect of 2,4-D on pre-harvest crop of citrus fruit under Florida conditions. *Proc. Fla Stn. hort Sci.* 7-11.

Gortych, Z. 1953. Delaying blossoming in fruit trees by means of growth substances. *Roczn. Nauk. Sot. Sec. A.* **66** (4) : 115-28.

Gowing, D.P. and Leeper, R.W. 1956. Some experiments on chemical induction of flowering in apple. From abstr. In *Pl. Physiol.* **31** : (Suppl.) XXXIV.

——— 1956. An hypothesis of the role of naphthalene acetic acid in flower induction in pineapple. *Am. J. Bot.* **43** : 411-18.

——— and Leeper, Robert, W. 1955. Induction of flowering in pineapple beta hydroxyethylhydrazine. *Science* **122** : No. 3185, 1267.

Griggs, W.H., Twakiris, T. and Detar, J.E. 1951. The effect of 2,4,5-TP applied during the bloom period on the fruit set of several pear varieties and on the shape, size, stem length, seed content and storage of Bartlett pears. *Proc. Am. Soc. hort. Sci.* **58** : 37-45.

Groszmann, H.M. 1950. Hormones and flowering in pineapples. *Od. Agric. J.* **70**; 88-89.

Gustafson, F.G. 1939. Auxin distribution in fruits and its significance in fruit development. *Am. J. Bot.* **26** : 189-94.

——— 1960. Influence of GA on setting and development of fruits in tomato. *Pl. Physiol.* **35** : 521-23.

Hamphill, D.D. 1949. The effect of plant growth-regulating substances on flower bud development and fruit set. *Ms. Bull.* 434.

Hield, H.Z. and Stewart, W.S. 1955. Fruit sizing sprays for oranges and grapefruit. *Calif Citogr.* 41-46; 58-61.

——— 1956. 2,4-D and 2,4,5-T as fruit sizing sprays for oranges and grapefruits. *Citrus Leaves* **26**(2) : 10-11.

——— Coggins, C.W. and Garber, M.J. 1958. Gibberellin tested on citrus. *Calif Agric* **12**(5) : 9-11.

Howell, M.J. and Wittwer, S.H. 1955. Further studies on flowering in sweet potato. *Proc. Am. Soc. hort. Sci* **66** : 279-83.

Jauhari, O.S. and Prasad, A. 1963. Effect of 2,4,5-T on fruit-set, size, ripening and quality of *phalsa* *Sci. & Cult* **29**(1) : 42.

Jones, L.T. 1955. Hormone sprays and their effect on the setting yield and vigour of currants grapevines. *J. Agric. W Aust.* **4** : 561-83.

Julliet, A. 1949 Treatments des tomatoes par less hormones parthenocarpiques (Treatment of tomatoes with parthenocarpy-inducing growth substances). *Phytoma* **2**(8) : 5-11.

Krishnamurthi, S. 1954. Effect of 2,4-D on *Solanum melongena*. *Curr. Sci.* **23** : 125-26.

——— and Subramanian, D 1955. Effect of 2,4-D on the fruit-set of the 3rd to 5th clusters of tomato *Sci. & Cult.* **20** : 399.

——— –, Randhawa, G.S. and Singh, J.P 1959 Effect of GA on fruit-set, size and quality in the Pusa seedless variety of grapes (*Vitis vinifera* L.). *Indian J. Hort* **11** : 1-4.

Kritskaja-Kryukova, L.M 1953. The protection of fruit trees from spring frosts (Russian). *Priroda* **42** (4) : 104-7.

Leopold, A.C. and Thimann, K.V. 1948. Auxins and flower initiation. *Science* **108** : 664.

———, and Guernsey, F.S. 1952. A role of malic acid in tomato fruit set. *Arch. Biochem. Biophys.* **41** : 64-73.

Luckwill, L.C. 1954. The auxins of apple seed and their role in fruit development. *Rep. and Commun 8th int. Bot Congr* II : 377-79.

——— 1959 Gibberellic acid can save pears. *Grower* **52** : 451-53.

Lund, H.A 1956 Growth hormones in the styles and ovaries of tobacco responsible for fruit development. *Am. J Bot* **43** : 562-68.

Marth, P.C 1952. Advances in the use of growth-regulating substances on deciduous fruits (Min. pat.). *13th int Hort. Congr London*, pp 10.

Muir, R M 1942 Growth hormones as related to the setting and development of fruit in *Nicotiana tabacum* *Am. J Bot* **29** : 716-20.

Murphey, H J. 1957. Growth regulators help shapbean production. *Ma. Fm. Res.* **5** (1) : 17-18.

Netaka, S. 1955. Floral initiation and fruit-set in lychee with special reference to the effect of Sod naphthalene acetate *Bot. Gaz* **117** : 126-34.

Nitsch, J P 1949 Growth and morphogenesis of the strawberry as related to axuin *Am J Bot* **36** : 827.

——— 1950. Growth and morphogenesis of the strawberry as related to auxin. *ibid* **37** : 211-15.

Osborne, D.J 1949. Attempts to produce parthenocarpic pears with growth substances. *Ann. appl Biol.* **36** : 550-53.

———, and Wain, R.L. 1951. Studies on plant growth-regulating substances-III. *J. hort. Sci.* **26** : 317-27.

Perez, V.M. 1949. Una hormona que adelanta la fructificacion de la pina (A hormone that hastens flowering in pineapples). *Suelo. Tico* **1** : 465-67.

Pickett, J.T. 1952. 2,4,5-T increases fruit size. *Am. Fruits* **72** (3) : 33.

Pieri, G. 1959. The effects of gibberellic acid on vines. *Riv. Vitic. Enol.* **12** : 409-18.

Podesva, J. 1955. The influence of some growth stimulators on the development and yield of vegetables (Russian). *Soorn. esl. Akad. Zomed. Ved. Rostal. Vyboba* **28** : 81-92.

Prince, F.S. and Blook, P.T. 1949. The effect of 2,4-D on potato tops and tubers when sprayed at full bloom stage. *Agron. J.* **41** : 219-20.

Randhawa, G.S. 1951. Effect of synthetic growth regulator on fruit set and maturity of early market field tomatoes. *Indian J. Hort.* **8** : 21-33.

———, and Sharma, B.B. 1962. Effect of plant regulators on fruit set, drop and quality of sweet oranges (*Citrus sinesis* Osbeck). *ibid* **19** (3&4) : 83-91.

———, and Nair, P.K.R. 1960. Studies on floral biology of plum grown under sub-tropical conditions. III. *ibid.* **17** (2) : 96-11.

——— Singh, J.P. and Khanna, S.S. 1959. Effect of GA and some other plant regulators on fruit set, size, total yield and quality in *Phalsa. ibid.* **16** (4) : 202-5.

———, ——— and Dhuria, H.S. 1959. Effect of GA, 2,4-D and 2,4,5-T on fruit-set, fruit drop and total yield in sweet lime (*Citrus limettiodes* Tanaka). *ibid.* **16** (4) : 206-9.

Raphael, T.D. and Richards, R.R. 1953. Tomatoes—further work on fruit setting with hormone spray. *Tesman J. Agric.* **24** : 374-77.

Schigeura, G. 1948. Blossom bud formation and fruit setting in the litchi. *Bienn. Ren. Hawaii agric. Exp. Stn* 1946-48.

Schrader, O.L. 1943. A study of certain factors influencing the yield of the Fordt hook busl line bean. *Bol. Minst. Agric. Bio. de. J.* **32** : 1 : 1-52 (*Hort. Abst.* 1946. XVI).

Singh, J.P. and Randhawa, G.S. 1959. Effect of GA and p-chlorophenoxy-acetic acid on growth and fruitfulness in strawberry. *Indian J. Hort.* **16** (1) : 14-17.

———, ——— and Jain, N.L. 1960. Response of strawberry to GA. *ibid.* **17** (1) : 21-30.

Singh, S.M., and Kacker, P.N. 1952. Effect of some hormones and their methods of application in parthenocarpy of tomato fruit. *ibid.* **9** (4) : 25-29.

Soost, R.K. 1958. Gibberellic acid on mandarin. *Calif. Agric.* **12** (5) : 5.

Stewart, W.S. 1951. Effects of 2,4-D and related substances on fruit drop, yield, size and quality of Washington Navel oranges. *Hilgardia* **21** : 301-29.

——— 1952. Effect of growth regulator sprays on set, size, abscission and storage of citrus fruits. *Rep. 13th int. hort. Congr. Lond* **2** : 1281-93.

——— and Klota, L.J. 1947. Some effects of 2,4-D on fruit drop and morphology of oranges. *Bot. Gaz.* **109** : 150-62.

———, Hield, H Z. and Brannaman. 1952. Effects of 2,4-D and related substances on fruit drop, yield, size and quality of valencia oranges. *Hilgardia* **21** : 301-29.

——— Halsey, D. and Ching, F T. 1958. Effect of potassium salt of GA on fruit growth of Thompson Seedless grapes. *Proc. Am. Soc. hort. Sci.* **72** : 165-69.

Stuivenberg, J.H M. 1943. Parthenocarpy. *Vakbl Biol.* No. 27.

Swarbrick, T. 1945. Use of growth-promoting substances in the prevention of apple drop following frost. *Nature, Lond.* **156** : 691.

——— 1948 Growth-promoting substance in horticulture. *ibid.* **161** : 656.

Teles Palbinha, R. 1952. On the flowering of *Apesocactus flagelliformis* (Miller). *Leur Portugal Acta Biol.* **3** : 275-80. (*Hort. Abstr.* 1953, 23).

Van Overbeek, J. 1946. Control of flower formation and fruit size in the pineapple. *Bot. Gaz.* **108** : 64-73.

———, Conklin, M.E. and Blakeslee, A.F. 1941. Chemical stimulation of ovule development and its possible relation to parthenogenesis. *Am. J. Bot.* **28** : 647-56.

Venktaratnam, L. 1949. Hormone-induced set and parthenocarpy in mango. *Curr. Sci* **18** : 409.

Vlitos, A.J. and Mendt, W 1954. Role of auxins in plant flowering. III. *Contrb. Boyce Thomson Inst. Pl. Res.* **17** : 413-17.

Weaver, R J. 1956. Plant regulators in grape production. *Bull. Calif. agric. Exp. Stn* 752

——— 1958. Effect of GA on fruit set or berry enlargement in seedless grapes of *Vitis vinifera. Nature, Lond* **181** : 851-52.

———, Krimbas, B.E. and Davidis, V.X. 1957. Response of Black Corinth and Thompson Seedless grapes to plant regulators under Greek conditions. *Proc. Am. Soc. hort. Sci.* **73** : 169-77.

——— and Williams, W.O. 1950. Response of flowers of Black Corinth and fruit of Thompson Seedless grapes to applications of plant regulators. *Bot. Gaz.* **111** : 477-85.

Whitaker, T W., and Pryor, D.E 1946. Effect of plant growth regulators on set of fruit from hand-pollinated flowers in *Cucumis melo. Proc. Am. Soc. hort. Sci* **48** : 417-22.

White, D.G. and Kennard, W G. 1950. Blossoming of fruits delayed by maleic hydrazide. *Science* **111** : 303.

Wittwer, S H. 1949 Effect of fruit setting treatment and solar radiation on yield and fruit size of greenhouse tomatoes. *Proc. Am. Soc. hort. Sci.* **63** : 349-54.

——— 1957. Gibberellins—new chemicals for crop production. *Farm Chemicals*, May.

——— and Murneek, A.E. 1957. Some effects of gibberellin on flowering and fruit setting. *Pl. Physiol.* **32** : 39-41.

CHAPTER III

Addicott, F.T. 1954. Abscission and Plant Regulators *Plant Regulators in Agriculture.* 99-116. Tukey H.B. Ed John Willy & Sons, N.Y.

——— and Lynch R L 1955. Physiology of abscission. *Ann. Rev. Pl. Physiol.* 211-38.

Audus, L.J. 1959. "*Plant Growth Substances.*" Leonard Hill (Books) Ltd., London.

Barlow, H.W.B. 1950. Studies in abscission I. *J. exp. Bot.* **1** : 261-81.

——— 1952. The importance of abscission in fruit production. *Rep. 13th int. Hort. Congr.* **1** : 145-52.

Batjer, L.P. 1941. Spraying to control pre-harvest drop of apples. *Proc. N.Y. St. hort. Soc.* **86** : 184-91.

——— 1942. Imperative in relation to effectiveness of pre-harvest drop sprays on apples. *Proc. Am. Soc. hort. Sci.* **40** : 45-48.

——— 1954. Plant regulators to prevent pre-harvest fruit drop, delay, foliation and blossoming and thin blossoms and young fruits. *Plant Regulators in Agriculture.* 117-31. Tukey H B. Ed John Willy & Sons, N.Y.

——— Siegelman, H.W., Rogress, B.L. and Gorhar dt. F. 1954. Results of 4 years tests of the effect of 2,4,5-trichlorophenoxy propionic acid on the maturity and fruit drop of apples in the north west. *Proc. Am. Soc. hort. Sci.* **64** : 215-21.

——— and Marth, P.C. 1941. Further studies with sprays in controlling pre-harvest drop of apples. *ibid.* **38** : 111-16.

Blake, M A. 1926. The growth of the fruit of the Elberta peach from blossom bud to maturity. *Proc. Am. Soc. hort. Sci.* **28** : 29-39.

Bradbury, D. 1929 A comparative study of the developing and aborting fruits of *Prunus cerasus.* *Am. J. Bot.* **16** : 525-42.

Bradley, M.V. and Crane, J.C. 1957. Effect of auxins on development of apricot seeds and seedlings. *Am. J. Bot.* **44** : 164.

Crane, J.C. 1956. The comparative effectiveness of several growth regulators for controlling pre-harvest drop, increasing size and hastening maturity of Stewart apricots. *Proc. Am Soc. hort. Sci* **67** : 153.

Cresimanco, F.A. 1951. The effect of hormone treatment on fruit drop in mandarin *Riv. Ortoflorofruittic ital* **35** : 270-72.

Crocker, A J. 1958. Fruit drop can be prevented. *Qd. Agric J.* **84** : 629-32.

Davison, R.M. 1952. Control of pre-harvest drop of Washington Navel Oranges. *N Z J. Sci. Tech, Sect. A* **34** : 306-12.

——— and Cederman, J A. 1951. Control of pre-harvest drop of sweet oranges by hormone sprays. *Orchard N.Z.* **25** (2) : 4-5, 7.

Dorsey, M.J. 1919. A study of sterility in the plum. *Genetics* **4** : 417-88.

Eames, A.J. and MacDaniels, L J. 1947. *An introduction of Plant Anatomy.* McGraw Hill Book Co., N.Y.

Edgerton, L J. and Hoffman, M B. 1948. Tests with 2,4-D for delaying fruit drop of McIntosh apples. *Proc. Am. Soc. hort. Sci.* **51** : 67-70.

——— 1951. The effectiveness of several growth regulators in delaying the harvest drop of the McIntosh apple. *ibid.* **57** : 120-24.

Emsweller, S L. and Stuart, N.L. 1948. Use of growth substances to overcome incompatibilities in *Lilium. ibid.* **51** : 581-89.

Erickson, L.C. 1951. Effects of 2,4-D on drop of sound and unsound Washington Navel Oranges. *ibid* **58** : 46-52.

——— 1952. Plant growth regulators for lemons. *Calif Citogr.* **37** :179-201.

Eteneau, J. and Praloran, J.C. 1954. Report on the effect of 2,4-D sprays on the drop of mature fruits (Citrus) *Fruits et Prim.* **24** : 125-57.

Frith, H.J. 1950. The reduction of drop of Washington Navel Oranges by 2,4-D. *J Aust. Inst. agric. Sci.* **16** : 101-4.

Gardner, F E., Marth, P.C. and Batjer, L P 1939. Spraying with plant growth substances to prevent apple fruit dropping *Science* **90** : 208-9.

———, ——— and ——— 1940. Spraying with plant growth substances for control of the pre-harvest drop of apples. *Proc Am. Soc. hort Sci.* **37** : 415-28.

Gowadi, A.G. and Avery, G.S. 1950. Leaf abscission and the so-called abscission layer *Annu. J. Bot.* **37** : 172-80.

Gokhale, A V. and Kantkar, V.K. 1951 Fruit drop in Alfonso mango and its control. *Proc. Indian Sci Congr* **38** (3) : 151.

Hall, W.C 1952. Evidence of auxin-ethylene balance hypothesis of foliar abscission. *Bot. Gaz.* 310-22.

Halse, N.J. 1952. Reduction of pre-harvest drop of Washington Navel Oranges by 2,4-D sprays. *J. Agric. W. Aust.* **1** : 327-30.

Harley, C.P., Moon, H.H., Regeimbal, L.O. and Green, E.E. 1946 2,4-D as a spray to reduce harvest drop of apples. *Proc. Am Soc. hort. Sci.* **47** : 39-43.

———, ——— and ——— 1948. Further studies on sprays containing 2,4-D and some related compounds for reducing harvest drop of apple. *ibid.* **50** : 38-44.

Harris, K.W. and Hansen, C.J. 1955 The effect of growth regulators on the drop of French *Prunus. ibid* **66** : 79-83.

Hield, H.Z. and Stewart, W.S. 1956. Fruit sizing sprays for Oranges and grapefruit. *Calif. Citogr.* **41** : 58-61.

———, Coggins, C.W and Garber, M.J. 1958. Gibberellin tested on *Citrus. Calif. Agric* **12** : 9-11.

Hoffman, M.B. and Edgerton, G.J. 1952. Comparison of naphthalene acetic acid, 2,4,4-trichlopropionic acid and 2,4,5-trichloro phenoxy acetic acid for controlling the harvest drop of McIntosh apples. *Proc. Am. Soc hort. Sci* **59** : 225.

Iwasaki, T. 1956 Observations on the dropping of fruits in some citrus varieties. *Bull Tokan Kinki Agric Exp. Stn Hort Div.* **3** : 1-16.

Howlett, Freeman, S. 1927. Some factors of importance in fruit setting studies with apple varieties. *Proc. Am. Soc. hort. Sci* **23** : 307-15.

Jones, L.T. 1951. Spraying to control pre-harvest drop in Washington Navel Oranges. *J. Agric. West. Aust.* **28** : 72-6

Kennard, W C. and Winter, H.W. 1956. The effects of 2,4,5-TP application on the size, maturation and quality of Amini mangoes. *Proc. Am Soc. hort. Sci.* **61** : 290-97.

Laibach, F. 1933. *Ber. dtsch. Bot. Ges.* **51** : 336-40.

Luckwill, L.C. 1948. The hormone content of the seed in relation to endosperm development and fruit drop in the apple. *J. hort Sci.* **24** : 32-44.

——— 1952 The mechanism of fruit drop in pome fruits and its control by synthetic growth substances. *Rep. 13th int. Hort. Cong.* **1** : 223-29.

——— 1954. The auxins of the apple seed and their role in fruit development. *Rep. and Common 8th Int. Bot. Congr. Sec* II. 377-9.

Marth, P C., Preston, W.H and Mitchell, J.W. 1955 Relative effectiveness of the mono- di- and tri-chlorophenoxy acetic acid in retarding abscission of mature apples. *Bot. Gaz.* **177** : 51-55.

Mc Alpin, D.M. and Merrett, D.C. 1949. To stop winter drop of grape fruit. *Orchard N.Z.* **22** (10) : 16-17.

Moon, H.H., Regeimbal, L O. and Harley, C.P. 1948. Some residual effects of sprays containing 2,4-D on apple trees. *Proc. Am. Soc. hort. Sci.* **51** : 81-84.

Mukherjee, S.K. 1949. The taxonomical value of the anatomical structures of the inflorescence axis of *Magnifera* L. *Indian J. bot. Soc* **28** : 161-71.

Murneek, A I. 1933. The nature of shedding and immature apples. *Mo. Agric. Exp. Stn Res. Bull.* 201.

Musahib-ud-din and Dinsa, H.S. 1946. The floral count and fruit set studies in some of the North Indian mangoes. *Punjab Fruit J.* **10** : 35-42.

Naidu, N. Anjaneyalu 1953. Immature fruit drop causes and cures. *South Indian Horticulture* **1** : 3-12.

Nankivell, W.T. 1952. Winter drop of grapefruit. *J. Dep. Agric. Vict.* **50** : 170-71.

Nitsch, J.P. 1955. Free auxins and free tryphtophane in strawberry. *Pl. Physiol.* **30** : 33-39.

Overholser, E.L., Overby, C.L. and Allmendinger, D.F. 1943. Three year study of pre-harvest sprays in Washington. *Proc. Am. Soc. hort. Sci.* **42** : 211-19.

Ramdhawa, G S., Singh, J P. and Dhuria, H.S. 1959. Effect of GA, 2,4-D and 2,4,5-T on fruit set, drop, size and total yield in sweet lime. *Indian J. Hort.* **16** (4) : 206-9.

———, Sharma, B B. and Jain, N.L. 1961. Effect of plant regulators on fruit drop, size and quality in sweet oranges. (*Citrus sinensis*, var Jaffa, Pineapple, Mosambi). *ibid.* **18** (3) : 177-86.

———, Jain, N L. and Sharma, B.B. 1961. Pre-harvest drop, size and quality of Jaffa oranges (*Citrus sinensis* Osbeck) by dipping in aqueous solutions of plant regulators. *ibid.* **18** (4) : 277-84.

——— and Sharma B B. 1962. Effect of plant regulators on fruit set, drop and quality of sweet oranges. *ibid* **19** (3&4) : 83-91.

Reece, P.C. and Hormic, G.E 1952. Some varietal response of Florida oranges to pre-harvest sprays. *Proc. Fla St. hort. Soc.* 88-91.

Scamen, J. 1944. Use of airplane in the orchards. *Proc. Wash. St. Hort.* Ass. **40** : 53-54.

Serr, E.F. and Forde, H I. 1952. Sprays for control of pre-harvest drop of peerless almonds. *Proc. Am. Soc. hort. Sci.* **60** : 193-96.

Singh Kirpal, K., Such Singh and Chadha, K L. 1959 Effect of some plant regulators on fruit drop in mango. *Indian J. Hort.* **17** (2) : 86-91.

Singh, U.P 1960. Unpublished work of Saharanpur.

Sites, J.W. 1954 Controlling pre-harvest drop of pineapple oranges with 2,4,5-T. *Proc. Fla St hort Soc.* pp 56-9.

Smock, R.M, Edgerton, L.J. and Hoffman, M.B 1952. Inhibition of the ripening effect of certain auxins on apples with maleic hydrazide. *Proc. Am. Soc. hort. Sci* **59** : 184-92.

———, ——— and ——— 1954 Some effect of stop drop auxins and respiratory inhibitors on the maturity of apples. *ibid.* **63** : 211-19.

Southwick, F.W., Demoranville, T E. and Anderson, J.F. 1953. The influence of some growth-regulating substance on pre-harvest drop, colour and maturity of apples. *ibid.* **61** : 155-62.

Stewart, W.S. 1952. Effect of growth regulator sprays on set, size, abscission and storage of citrus fruit (Min. Pao.) *13th int. Hort. Congr. London*, p. 6.

——— and Klotz, L.J. 1947 Some effects of 2,4-D on fruit drop and morphology of oranges. *Bot. Gaz.* **108** : 150-62.

——— and Parker, E.R. 1947. Preliminary studies on the effects of 2,4-D on pre-harvest drop, yield and quality of grapefruit. *Proc. Am. Soc. hort. Sci.* **50** : 187-94.

———, Klotz, L.J. and Hield, H.Z. 1947. Effect of plant growth regulators on orange fruit drop. *Calif. Citogr.* **32** : 314-16.

——— 1947. 2,4-D sprays per control of navel orange drop. *ibid.* **33** : 49, 77 and 78.

——— and Parker, E.R. 1948. Sprays to reduce fruit drop from grape fruit trees. *ibid.* 33 : 332, 351-53.

——— and Hield, H.Z. 1950. Effects of 2,4-D and 2,4,5-T on fruit drop and production of lemon trees. *ibid.* **35** : 93.

——— and ——— 1950. Effects of 2,4-D and 2,4,5-T on fruit drop, fruit production and leaf drop of lemon trees. *Proc. Am. Soc. hort. Sci.* **55** : 163-71.

———, Klotz, L.J. and Hield, H Z. 1951. Effects of 2,4-D and related substances on fruit drop, yield, size and quality of Washington Navel Oranges. *Hilgardia* **21** : 161-93.

———, Hield, H.Z. and Brannaman, B.L. 1952. Effects of 2,4-D and related substances on fruit drop, yield, size and quality of Valencia oranges. *ibid.* **21** (11) : 301-29.

——— and Parker, E.R. 1954. Effects of 2,4-D and related substances on fruit drop, yield, size and quality of grapefruit. *ibid.* **22** : 623-41.

Swarbrick, T. 1943. The influence of certain sprays on pre-harvest drop of apples-II. *A. R. Long. Ashton. Res. Stn, 1942*, 29, 31.

——— 1945. The prevention of pre-harvest of apples. *A.R. Long. Ashton. Res. Stn, 1944*, p. 30-36.

Thompson, A.H. 1951. The effect of 2,4,5-TP sprays in delaying the pre-harvest drop of several apple varieties. *Proc. Am. Soc. hort. Sci.* **58** : 57-64.

——— 1952. Further experiments with 2,4,5-TP sprays for control of the pre-harvest drop of apples. *ibid.* **60** : 175-83.

Van Overbeek, J. 1952. Agricultural application of growth regulators and their physiological basis. *Annu. Rev. Pl. Physiol.* **3** : 87-108.

———, Racusen, D.W., Taganni, M. and Hugheo, W J. 1957. Simultaneous analysis of auxin and gibberellin. *Pl. Physiol.* **32**.

——— 1959. Auxins. *Bot. Rev.* **25** (2) : 271-337.

Vyvyan, M.C. 1946 a. Fruit fall and its control by synthetic growth substances. *Tech. Comm. No. 18. Imp. Bur. Hort. & Plantation Crops.*

——— 1946 b. Experiments with growth substance sprays for reduction of pre-harvest drop of fruit. *J. Pomol. hort. Sci.* **22** : 11-37.

——— 1949. The use of growth substances to control the shedding of fruit. *Ann. apple Bull.* 36 : 553-58.

——— and Barlow, H.W.B. 1947. Use of sprays to control fruit drop. *A.R.E. Mall. Res. Stn, 1946*, 83-87.

——— and ——— 1948 a. Use of sprays to control fruit drop. III. *A.R. East. Mall. Res. Stn, 1947*, 108-10.

——— and ——— 1948 b. Use of sprays to control fruit drop. III. *A.R. East. Mall. Res. Stn. 1947*, 108-10.

——— and Trowall, 1951. Use of sprays to control fruit drop. VII. *A.R.E. Mall. Res. Stn, 1950*, 111-15.

Wagle, B.V. 1928. Studies in the shedding of mango, flowers and fruits. Part. I. *Mem. Dep. Agric. India* **15** (8) : 219-49.

Went, F.W. 1938. Specific factors other than auxin effecting growth and root formation. *Pl. Physiol.* **13** : 55-80.

Wester, H.V. and Marth. P.C. 1950. Growth regulators prolong the bloom of oriental flowering cherries. *Science* **111** : 611.

Wetmore, R.H. and Jacobs, W.P. 1953. Studies on abscission, the inhibiting effect of auxin. *Amer. J. Bot.* 40 : 272-76.

White, D.G. 1953. Promotion of red colour of apples. II. *Proc. Am. Soc. hort. Sci.* **61** : 180-84.

Wright, S.T.C. 1956. Studies of fruit development in relation to plant hormones. III. *J. hort. Sci.* **31** : 196-211.

CHAPTER IV

Abbott, D.L. 1953. Growth substances as fruit thinning agents for apples and pears. *Prog. Rep. A.R. Wong Ashton Agric. Hort. Res. Stn for 1952* : pp. 40-44.

——— 1954. Growth substances as fruit thinning agent for apples and pear. *Prog. Rep. A.R. Wong Ashton Agric. Hort. Rec. Stn for 1953*, p. 58-63.

——— 1957. Growth substances as fruit thinning agents for apples. *Prog. Report-A.R. Wong Ashton Agric. Hort. Res. Stn. 1956* : p 59-60.

Addicott, F.T. 1943. Pollen germination and tube growth as influenced by pure growth substances. *Pl. Physiol.* **18** : 270-79.

Auchter, E.C., and Roberts, J.W. 1935. Spraying apples for the prevention of fruit set. *Proc Am. Soc. hort. Sci.* **32** : 208-12.

Batjer, L.P. 1952. Factors affecting results with dinitro thinning sprays. *Proc. 4815 Ann. Meeting Wash. St. Hort. Assoc.* : pp. 158-61.

——— 1954. *Fruit drop. Foliation and Thinning* U.S.D.A. Bull. : 131.

——— and Thompson, A.H. 1948. Three years' results with chemical thinning of apples in the north-west. *Proc. Am. Soc. hort. Sci.* **52** : 164-72.

———, and Uota, M. 1951. Effect of 2,4,5-TP on fruit set of pears and apples. *ibid.* **58** : 33-36.

Blair, D.S. 1952. Chemical thinning of apples. *89th A.R.N. Scotia Fr. Gr. Assoc. 1952*, pp. 21-22.

Blommaert, K.J. 1954. Thinning apples at blossom time with hormone sprays. *Fmg S. Afr.* **29** : 295-96.

Brought, C.R. 1951. Blossom thinning sprays for apples. A progress report. *J. Dep. Agric. Viet.* 49 : 451-54, 458.

Burkholder, C.L. and McCown, M. 1941. Effect of scoring and of naphthalene-acetic acid and amide spray upon fruit set and of the spray upon pre-harvest fruit drop. *Proc. Am. Soc. hort. Sci.* 38 : 117-20.

Davidson, J.H., Hammer, O.H., Beimer, C.A. and Dutton, W.C. 1945. Thinning apples with the sodium salt of NAA. *Mich. Agric. Exp. Stn Q. Bull.* **27** (3) : 352-56.

Davison, R.M. 1955. The use of chemical thinning sprays on apple trees in New Zealand. *N.Z.J. Sci. Tech. Sec. A.* 37 : 1-7. (*C.F.H.A.* **25** (4) : 536.

Detar, J.E., Griggs, W.H. and Crane, J.C. 1950. Effect of growth regulators on set of Bartlett pears. *Proc. Am. Soc. hort. Sci.* **55** : 137-39.

Dodge, F.N. 1944. Reducing the set of pecan nuts by spraying in flower with phytotoxicants. *ibid.* **45** : 59-62.

Edgerton, L.J. and Hoffman, M.B. 1952. The effect of thinning peaches with bloom and post bloom sprays on the cold hardiness of fruit buds. *ibid.* **60** : 155-59.

——— and ——— 1955. Effect of N-1 naphthyl phathalamic acid on fruit set of peaches. *Science* **121** : 467-68.

Erickson, L.C. and Richards, S.J. 1955. Influence of 2,4-D and soil moisture on size and quality of Valencia orange. *Proc. Am. Soc. hort. Sci.* **65** : 109-12.

Fernquiet, J. 1957. Chemical fruit thinning. *Suer. Pomol. Foren. Arsskr.* pp : 69-73 (C.F. H.A. 28 (4) : 539).

Fisher, D.V. 1953. Chemical fruit thinning with concentrate spray machines. *Proc. Am. Soc. hort. Sci.* **61** : 144-48.

Flory, W.S. (Jr.) and Moore, R.C. 1947. An early post blossom thinning agent for york apples. *ibid.* **49** : 33-34.

Gardner, U.R., Merill, T.A. and Peteniy, H.G. 1939. Thinning apple crop by spray at blooming period—a preliminary report. *ibid.* **37** : 147-49.

Greene, L. 1943. Growth regulators and fruit set with starking apples. *ibid.* **42** : 149-50.

Harley, L.P., Moon, H.H. and Regeimbal, L.V. 1957. Effects of the additive Tween 20 and relatively low temperatures on apple thinning by NAA sprays. *ibid.* 69 : 21-27.

Harris, W.B. 1957. Thinning weight cling peaches. *J. Dep. agric. Sci. Aust.* **61** : 9-11.

HARRIS, O.W. AND SMITH, C.L. 1957. Chemical thinning of pecan nut crops. *Proc. Am. Soc. hort. Sci.* **70** : 204-08.

HARTMAN, H.T. 1952. Spray thinning of olives with naphthaleneacetic acid. *ibid.* **69** : 187-95.

HAYES, W.B. 1957. *Fruit Growing in India.* Kitabistan, Allahabad (India).

HEMPHILL, D.D. 1954. Spray thinning apples. *Am. Fr. Grow.* **74** (2) : 36-39.

HIBBARD, A.D. and MURNEEK, A.E. 1950. Thinning peaches with hormone sprays. *Proc. Am. Soc. hort. Sci.* **56** : 65-69.

HIGDON, R.J. and GRIM, J.H. 1956. The way to thin pears. *Agric. Res. Wash.* **5** : (6) : 15.

HOFFMAN, M.B. 1954. Thinning apples with hormone sprays. *Proc. 99th Annu. Meet. N.Y. St. Hort. Sci.* pp : 137-41.

———. and GELUEVE, J.D. 1943. The annual bearing of wealt apple trees as influenced by thinning the fruit at blossom time with a caustic spray. *Proc. Am. Soc. hort. Sci.* **42** : 185-86.

HORSEFALL, F. and MOORE, R.L. 1957. Chemical thinning of apples and peaches. *Res. Rep. Va. Agric. Exp. Stn.* (*C.F. H.A.* **28** (3) : 358).

HOUTER, P.J. 1952. The use of mist sprayers for chemical fruit thinning. *Jaarwst Inst. Tuinh. Tech. Wageningen.* pp. 4 (*C.F. H.A.* **24** (1) : 31).

KASAHARA, J. and OGURO, E. 1956. Studies on fruit (blossom) thinning of apples by hormone sprays. 1. Thinning effects on several commercial varieties. *J. Hort. Ass. Japan* **24** : 233-39.

KELLEY, V.W. 1953. Results of the 1952 chemical peach thinning tests. *Trans. Ill. St. hort. Soc. for 1952, 1953.* **86** : 228-31.

——— 1954. Chemical thinning of peaches and apples in 1954. *Trans. Ill. Hort. Soc. for 1954.* **88** : 211-19. (*C.F. H.A.* **25** (4) : 536).

KENWORTHY, A.L. 1947. A spray mixture useful to thin apples after bloom. *Proc. Am. Soc. hort. Sci.* **49** : 35-36.

LALATTA, F. 1954. Thinning trials on the peach variety S. Anna Balducci ; *Riv. Fruttic.* **16** : 126-39 (*C.F. H.A.* **25** (2) : 201).

——— 1957. Thinning tests on the peach variety S. Anna di Balducci. *Ann. Sher. Agro.* **11** : 1095-1125 (*C.F. H.A.* **28** (2) : 187).

——— and SFORZA, L.C. 1956. Experiments on chemical thinning of Olives. *Olivicoltura* **9** : 7.

LANGER, C.A. 1952. Effect of MH on the thinning of peaches during 3 successive years. *Q. Bull. Mich. Agric. Exp. Stn* **35** : 209-13.

LEOPOLD, A.C. 1955. *Auxins and Plant Growth.* Univ. of Calif. Press.

LIARD, O. 1958. Note on the preliminary results of chemical thinning. *Fruit. helge.* **26** : 105-10 (*C.F. H.A.* **28** (4) : 539).

LILLELAND, U.K. and KOCH, E.C. 1958. Spray thinning of Newton apples. *Calif. Agric.* **12** (4) : 7-8.

LONGLEY, R.P. 1954. Fruit thinning and its effect in promoting annual bearing in apples. *A. R. Nova. Scotia Fr. Gr. Ass.* pp : 147-50.

LU, C.S. and ROBERTS, R.M. 1952. Effect of temperature on setting of delicions apples. *Proc. Am. Soc. hort. Sci.* **59** : 177-83.

LUCKWILL, L.C. 1948. Hormone content of the seed in relation to endosperm development and fruit drop in the apple. *J. hort. Sci.* **24** : 32-44.

——— 1953. Studies of fruit development in relation to plant hormones. II. The effect of NAA on fruit set and fruit development in apple. *ibid.* **28** : 24-40.

MILLER, P.R. and ERKSINE, D. 1949. The prevention of fruit formation on some ornamental trees. *Proc. 25th Conf.* pp. 88-99 (c.f. *Plant Regulators in Agriculture* by H.B. Tukey pp. 130).

MITCHELL, A.E. 1952. Chemical fruit thinning. *Am. Fr. Grow.* **72** (2) : 56-58.

MURNEEK, A.E. 1944. Recent developments in regulating the apple crop on trees. *Trans. Ill. Stn hort. Sci.* **77** : 262-68.

——— 1950. Relative value of hormone sprays for apple thinning. *Proc. Am. Soc. hort. Sci.* **55** : 127-36.

——— 1952. Plant growth regulators during fertilization and post fertilization periods. *Proc. Am. Soc. hort. Sci.* **59** : 207-17.

——— and TEUBNER, F.G. 1953. The dual action of naphthaleneacetic acid in thinning of apples. *ibid.* **61** : 149-54.

RICHARDS, R.R. 1956. Apples and pear crop regulation by thinning. *Tasn. J. Agric.* **27** : 205-09 (*C.F. H.A.* **27** (2) : 185).

RONZONI, G. 1954. Fruit thinning tests on mid-season and J.H. Hale peaches. *Riv. Fruttic.* **16** : 122-23. (*C.F. H.A.* **25** (1) : 30).

SHEPARD, P.H. 1939. Spraying apples for the prevention of fruit set. *Missouri Stn Fr. Exp. Stn Circ.* **28** : 1-27.

SOUTHWICK, F.W. AND WEEKS, W.D. 1950. Some attempts to thin apple with NAA type materials after calyx. *Proc. Am. Soc. hort. Sci.* **56** : 169-73.

——— 1952. The influence of chemical thinning treatments on yield and flowering of apples. *ibid.* **60** : 165-72.

——— 1957 The influence of NAA and naphthaleneacetamide during a four year period of thinning and subsequent flowering of apples. *ibid.* **69** : 28-40.

STRUCKMEYER, B.E. 1951. Thinning apples with chemical. *Wis. Hort.* **41** : 168-70.

——— and ROBERTS, R.H. 1950. Possible explanation of how NAA thins apple. *Proc. Am. Soc. hort. Sci.* **56** : 76-78.

SWANSON, C.P., LAVELLA, G. and GOODGAL, S.H. 1949. Ovule abortion in *Tradescantia* as affected by aqueous solutions of 2,4-D. *Am. J. Bot.* **36** : 170-75.

TENEMHAUM, L.J. 1954. Chemical thinning of fruit. *Rev. Fac. Agron. Eva. Peron.* **30** : 51-57 (*C.F. H.A.* **25** (2) : 201).

TEUBNOR, F.G. and MURNEEK, A.E. 1955. Embryo abortion as mechanism of 'hormone' thinning of fruits. *Res. Bull. Mo. Agric. Exp. Stn* **590** : 88.

THOMPSON, A.H. 1954. Consideration in the use of chemical thinning sprays on apple trees. *St. Hort. Ass. Pa. News* **33** (1) : 29-38 (*C.F. H.A.* **24** (3) : 334).

URIU, K., MILLELAND, O. and KOCH, E.C. 1958. Spray thinning Newton apples. *Calif. Agric.* **12** (4) : 7-8.

VERNER, L., and DEL, F.F. 1949. Thinning apples and peaches with blossom sprays. *Proc. 45th Annu. Mtg. Wash. St. Hort. Abs.* pp : 174-82. (*C.F.H.A.* **20** (2) : 87).

Vrijhof, B. and Oele, L.C. 1951. Chemical blossom thinning of some apple, pear and plum varieties. *Meded. Dir. Tuints.* **14** : 232-49.

Wurgler, W. and Aubert, P. 1955. Effect of fruit thinning on apple quality and biennial bearing. *Landed Ju. Schweiz.* **4** : 809-14. (*C.F. H.A.* **27** (2) : 218).

CHAPTER V

Aberg, E. 1954. Hormone preparations against weeds in potatoes. *Lautns. Sveuskt Land.* 20-34. *Food Crop Abstr.* 9 (1) : 1956(1).

Akamine, E.K. 1948. Plant Growth regulators as selective herbicides. *Univ. Hawaii Agric. Exp. Stn Circ. Honolulu*, 26.

Akers, T.J. and Fang, S.C. 1956. Studies in plant metabolism. VI. Effect of 2,4-D on the metabolism of aspartic acid and glutamic acid in the bean plant. *Pl. Physiol.* **31** : 34-37.

Alban, E.K. 1950. The use of chemicals for weed control with canning crops. *Mimeo. Ohio State Univ. Dep. Hort.*

——— and Combs, L.M. 1949. Pre- and post-emergence weed control in vegetable crops. *Proc. Sixth Annu. North Central Weed Control Conf.*

Aldrich, R.J. 1952. Factors affecting the pre-emergence use of 2,4-D on corn. *Weeds* **1** (3) : 338-45.

——— and Willard, C.J. 1949. The effect of post-emergence 2,4-D on corn. *Res. Rep. Sixth Annu. North Central Weeds Control Conf.* pp : 55-56.

Altona, R.E. 1950. A preliminary report on the control of weed in maize with MCPA and 2,4-D. *S. Afr. J. Sci.* **46** : 295-96.

Anderson, J.C. and Wolf, D.E. 1947. Pre-emergence control of weeds in corn with 2,4-D. *J. Am. Soc. Agron.* **39** : 341-52.

Anonymous, 1945. Methoxone. The new selection weed killer. *Chem. Agric.* (*Lond.*) **53** : 331-32.

——— A new agricultural weed killer. *Trop. Agric., Trin.* **22** : 199.

——— Agricultural weed killer. A revolutionary discovery. *Chem. Agric.* (*Lond.*) **52** : 283.

Arakeri, H.R. 1957. Chemicals to kill weeds. *Indian Fmg* **7** (3) : 23-27.

Avery, G.S. and Johnson, E.B. 1947. *Hormones and Horticulture.* McGraw-Hill Book Company, Inc., New York and London.

Bakke, A.L. *et al.* 1944. Relation of cultivation to depletion of root reserves in European Bind-weed at different soil horizons. *J. agric. Res.* **69** : 137-47.

Barrons, K.C. and Grigsby, B.H. 1945. The control of weeds in canning peas with chemical sprays. *Mich. Agric. Exp. Sta. Q. Bull.* **28** : 145.

Beal, J.M. 1944. Further observations on the telemorphic effects of certain growth regulating substances. *Bot. Gaz.* **106** : 165-78.

Blackman, G.E. 1945. A comparison of certain plant growth substances with other selective herbicides. *Nature, Lond* **155** : 500-01.

——— 1946. Weed control in cereals by chemical methods. *J. Min. Agric.* (*Gt. Britian*). **53** : 16-22.

——— 1949. Selective weed control in horticulture. *Sci. Hort.* **9** : 117-22.

——— 1956. *The Chemistry and Mode of Action of Plant Growth Substances.* pp 253-59. Wani R.L. and F. Wightman. Ed. Butterworths Sci. Pub. Lond. pp : 312.

———, Templeman, W.G. and Halliday, D.J. 1951. Herbicides and selective phytotoxicity. Part I and II. *Annu. Rev. Pl. Physiol.* **2** : 199-231.

Bonnder, J. and Bandurski, R.S. 1952. Studies of the physiology, pharmacology and biochemistry of auxins. *ibid.* **3** : 59-86.

Bradbury, D. and Ennes, W.B. 1952. Stomatal closure in kidney bean plants treated with ammonium 2,4-dichlorophenoxyacetate. *Am. J. Bot.* **39**: 324-28.

Brown, J.W. 1946. Effect of 2,4-D on the water relations, the accumulation and distribution of solid matter and the respiration of bean plants. *Bot. Gaz.* **107**: 332-43.

Carlson, R.F. and Moulton, J.E. 1954. Plant regulator for weed control in lawn garden, orchard and nursery. *Plant Regulators in Agriculture* in H.B. Tukey (Ed.) John Willy Sons, INC., New York.

———, ——— and Mamner, C.L. 1950. Protection of strawberry plants with activated carbon in pre-planting application of 2,4-D. *Proc. Am. Soc. hort. Sci.* **55** : 268-70.

Carlyle, R.E. and Thorpe, J.D. 1947. Some effects of ammonium and sodium 2,4-diacetate on legumes and the *Rhizobium* bacteria. *J. Am. Soc. Agron.* **39** : 929-36.

Crafts, A.S. 1946. Selectivity of herbicides. *Pl. Physiol.* **21** : 345-61.

——— 1948. Weed control in tropics. *Science* **107** : 196.

——— 1953. Herbicides. *Annu. Rev. Pl. Physiol.* **4** : 253-82.

Derose, H.R. 1951. Crabgrass inhibition with isopropyl chlorophenyl carbonate. *J. Am. Soc. Agron.* **43** : 139-42.

Duncun, Paul 1946. The British develop a new weed killer. *Agric. Chem.* **1** (4): 37.

Ennis, W.B., Swason, C.P., Allard, H.W. and Boyd, F.F. 1946. Effects of certain growth regulating compounds on Irish potatoes. *Bot. Caz.* **107** : 568-74.

Frayer, J.D. and Evans, S.A. 1956. *Proc. Brit. Weed Control Conf. 3rd meet. Blackpool.* 553-68.

Freeland, R.O. 1950. Effects of 2,4-D and other growth substances on photosynthesis respiration in Anarcharis. *Bot. Gaz.* **111** : 319-24.

French, R.C. and Beevers, H. 1953. Respiratory and growth response induced by growth regulators and allied compounds. *Am. J. Bot.* **40** : 660-66.

Fults, J.L. and Johanson, M. 1950. A cumulative fluorescent chemical found in certain plants treated with 2,4-D identified as soopletin. *West. Weed Conf. Abstr. Jan. for 1950.*

Hamner, C.L. and Tukey, H.B. 1944. Herbicidal action of 2,4-D and 2,4,5-T on Bind-weed. *Science* **100** : 154-55.

——— and ——— 1944. Selective herbicidal action of mid summer and fall applications of 2,4-D. *Bot. Gaz.* **106** : 232-45.

——— and ——— 1954. Principles of plant growth and how plant growth regulators act. *Plant Regulator in Agriculture.* H.B. Tukey (Ed.). John Willy & Sons. INC, New York, pp. 15-28.

Hance, F.E. 1948. Recent developments in weed control. *Science* **108** : 278.

——— 1949. Weed control in Hawiian sugarcane lands development in ,use of 2,4-D. *Hawaii Pl. Rec.* **53** : 93-105.

Harris, L.E. and Hyslop, G.R. 1942. Selected sprays for weed control in crops. *Oregon Agric. Exp. Stn Bull.* **40** : 1-31.

Havis, J.R. and Sweet, R.D. 1947. The value of certain aromatic naphthas and growth regulators as soil treatments for weed control in vegetables. *Proc. Am. Soc. hort. Sci.* **49** : 325-31.

Handerson, J.H.M., Miller, I.H. and Deese, D.C. 1954. Effect of 2,4-D on respiration and on destruction of IAA on oat and sunflower tissues. *Science* **120** : 710-12.

Holmes, E. 1958. The role of industrial research and development in weed control in Europe. *Weeds* **6** (3) : 245.

Jones, R.L., Matalfe, T.P. and Sexton, W.A. 1949. The relationship between the constitution and the effects of chemical compounds on plant growth, 1,2-phenoxyethylomine derivatives. *Biochem. J.* **45** : 134-49

Kaul, R.N. and Raheja, P.C. 1952. A review of weeds and their control. *Sci. & Cult.* **18** (3) : 124-29.

Korlyuk 1955. Treatment of summer wheat sowings by 2,4-D mixed with mineral, fertilizers. *Zembdelie.* (1) : 104. Zhur Bio 1932. (Translation).

Leapor, J.M.F. and Bishop, J.R. 1951. Relation of Halogan position, physiological properties in Mono-, Di- and Tri-Chlorophenoxy acetic acids. *Bot. Gaz.* **113** : 250-63.

Lee Ling 1952. Weed control by growth regulating substances.' *F.A.O. Agric. Studies* **13** : 35.

Loustalot, A.J., Morris, M.P., Garcia, J. and Pagan, C. 1953. 2,4-D effects phosphorus metabolism. *Science* **118** : 627-28.

Luecke, R.W., Hamner, C.L. and Sell, H.M. 1949. Effect of 2,4-D on the content of thiamin, riboflorin, nicotinic acid, pantothenic acid and carotene in stem and leaves by red kidney been plants. *Pl. Physiol.* **24** : 246-8.

Marth, P.C. and Mitchell, J. 1946. Period of effective weed control by the use of 2,4-D. *Science* **104** : 77-79.

——— and ——— 1947. Selective herbicidal effect of 2,4-D applied to turf in dry mixtures with fertilizer. *Bot. Gaz.* **108** : 414-20.

Mitchell, J.W. and Brown, J.W. 1945. Effect of 2,4-D on the readily available carbohydrate constituents in an annual morning glory. *Ibid.* **107** : 120-29.

——— and — —— 1946. Movement of 2,4-D acid stimulus and its relation to the translocation of organic food materials in plants. *ibid.* **107** : 393-407.

——— and ——— 1947. Relative sensitivity of dorment and germinating seeds to 2,4-D. *Science* **106** : 266.

——— and Paul, C.M. 1947. *Growth Regulators for Garden, Field and Orchard.* Univ. of Chicago Press, Chicago.

Muir, R.M. and Hansch, C. 1955. Chemical constitution as related to growth regulators action. *Annu. Rev. Pl. Physiol.* **6** : 157-76.

Norman, A.G. 1946. Studies on growth regulating substances. *Bot. Gaz.* **107** : 475.

——— 1954. The chemical nature of plant regulators. *Plant Regulators in Agriculture.* Tukey, H.B. (Ed.). John Willy & Sons, INC, New York.

———, Minarik, C.E. and Weintraub, R.L. 1950. Herbicides. *Annu. Rev. Pl. Physiol.* **1** : 141-68.

Pincus, G. and Thimann, K.V. 1948. *The Hormones.* Academic Press, New York.

Pridham, A.M.S. 1947. Delayed action of 2,4-D on trees, shrubs and perennials. *Proc. Am. Soc. hort. Sci.* **50** : 395-97.

Rasmussen, L.W. 1947. The physiological action of 2,4-D on daudelion (*Taraxacum officinale*). *Pl. Physiol.* **22** : 377-92.

Rhodes, A., Templeman, W.G. and Thruston, M.N. 1950. The effect of plant growth regulator, 4 chloro 2 methyl phenoxyacetic acid on the mineral and nitrogen contents of plants. *Ann. Bot. Lond.* **14** : 181-98.

Robbins, W.W., Crafts, A.S. and Raynor, R.N. 1953. *Weed Control.* McGraw-Hill Pub. Ltd., New York, London and Toronto, 2nd (Ed.), pp. 503.

Ryker, T.C. 1947 Studies on the chemical control of rice weeds. *J. Am. Soc. Agron.* **39** : 395-402.

——— 1948. Weed control in rice with 2,4-D. *La. Agric. Exp. Stn Bull.* 427.

——— and Brown, C.A. 1947. The use of 2,4-D in rice fields for the control of weeds. *Agric. Exp. Stn Bull.* **411** : 1-14.

Sell, H.M., Weeke, R.W., Taylor, B.N. and Hamner, C.L. 1949. Changes in the chemical composition of the stems of red kidney bean plants treated with 2,4-D. *Pl. Physiol.* **24** : 295-99.

Shivpuri, T.N. and Tyagi, B.P. 1950. Methoxone as an eradicator of the weed *Pluchea lanceolata* (Vern. *Baisurai*). *Indian Fmg* **11** : 116.

Singh, J.P. and Hamner, C.L. 1956. The relation of chemical structure to biological activity in certain organic compounds. *Indian J. Hort.* **13** (3) : 1-32.

Skoog, F. 1951. *Plant Growth Substances.* Univ. of Wisconsin Press, Madison.

Skoss, J.D. 1955. Structure and composition of plant cuticle in relation to environmental factors and permeability. *Bot. Gaz.* **117** : 55-72.

Slade, R.E. Templeman, W.G. and Sexton, W.A. 1945. Plant growth substances as selective weed killers. *Nature, Lond.* **155** : 497-98.

Smith, F.G., Hamner, C.L. and Garlson, R.F. 1947. Changes in food reserves and respiratory capacity of bindweed tissues accompanying herbicidal action of 2,4-D. *Pl. Physiol.* **22** : 58-65.

Stamper, H.R. 1956. New developments in weed and grass control in sugarcane in Tonsiana. *Rep. Loviscana Agric. Exp. Stn Lousiana.*

Struckmeyer, B.E. 1951. Comparative effects of growth substances in stem anatomy. In Skory (Ed.). *Plant Growth Substance.* Univ. of Wisconsin Press, Madison.

Swnason, C.P. 1945. Histological responses of the kidney bean to aqueous sprays of 2,4-D. *Bot. Gaz.* **107** : 527-31.

Synerholms, M.E. and Zimmerman, P.W. 1947. Preparation of a series on W-2,4-D alphatic acids and some related compounds with a consideration of their biochemical role on a plant growth regulators. *Contrb. Boyce Thompson Inst. Pl. Res.* **14** : 369-82.

Taylor, D.L. 1946. Observations on the growth of certain plants in nutrient solutions containing synthetic growth-regulating substances. I. Some effect of 2,4-D acid. *Bot. Gaz.* **107** : 597-611.

Tukey, H.B. 1950. Persistence of 2,4-D in plant tissue. *Science* **112** : 282-93.

———— 1954. *Plant Regulators in Agriculture.* John Willey & Sons INC, New York.

————, Hamner, C.L., and Imhoff, B. 1945. Histological changes in Bind weed and sow thistle, following application of 2,4-D herbicidal concentrations. *Bot. Gaz.* **107** : 62-73.

Tullis, E.C. 1948. Experiments with 2,4-D for controlling weeds in rice fields in South Eastern Texas. *Texas Agric. Exp. Sta. Prog. Rep.* 115.

Vachani, N.V. and Chaudhry, M.S. 1955. Selective herbicides for weed control. *Rice News Teller* **3** : 129-35.

Van Overbeek, J. 1947. Use of synthetic hormones as weed killers in tropical agriculture. *Econ. Bot.* **1** : 446-59.

———— 1952. Agricultural application of growth regulators and their physiological basis. *Annu. Rev. Pl. Physiol.* **3** : 87-108.

———— and Velez, I. 1946. Use of 2,4-D as a selective herbicide in the tropics. *Science* **103** : 472-73.

————, Blondean, R. and Horne, V. 1951. Difference in activity between 2,4-D and other auxins and its significance in herbicidal action. *Pl. Physiol.* **26** : 687.

Veldstraw, H. 1944. Researches on plant growth substances. IV. The relation between chemical structure and physiological activity. *Enzymologia* **110** : 97-137.

———— and Booij, H.L. 1949. Researches on plant growth regulators. XVII. Structure and activity on the mechanism of action. *Biochem. Biophys. Acta* **3** : 278-312.

Verma, R.D. and Bhardwaj, R.B.L. 1957. Chemical weed control in wheat. *Indian J. Agron.* **2** (2) : 101-02.

———— and ———— 1958. A better way of tackling weeds in sugarcane. *Indian Fmg* **8** (3) : 29-32.

———— and Raheja, P.C. 1958. Progress of chemical weed control in India. *Indian J. Agron.* **2** (4) 243-53.

Waston, D.P. 1948. An anatomical studies of the modification of the bean leaves as a result of treatment with 2,4-D. *Am. J. Bot.* **35** : 543-55.

Weaver, R.J. and De Rose, H.R. 1946. Absorption and translocation of 2,4-D. *Bot. Gaz.* **107** : 509-21.

Wedding, R.J., Erickson, L.C. and Brannaman, B.L. 1954. Effect of 2,4-D on photosynthesis and respiration. *Pl. Physiol.* **29** : 64-69.

Weiyt, F.W. and Thimann, K.V. 1927. *Photohormones.* The Macmillan Co., New York.

Wood, J.W., Mitchell, J.W. and Irving, G.W. (Jr.) 1947. Translocation of a radio-active plant growth regulator in bean and barley plants. *Science* **105** : 337.

Zimmerman, P.W. and Hitchcock, A.E. 1942. Substituted phenoxy and benzoic acid growth substances and the relation of structure to physiological activity. *Contrb. Boyce Thomson Inst. Pl. Res.* **12** : 321-43.

———— 1948. *Plant hormones. Annu. Rev. Biochem.* **17** : 601-26.

CHAPTER VI

Anonymous 1958. *A report on FW-450, a selective gametocide.* Rohm & Haas Co., Philadelphia, Pa.

———— 1959. *Progress report on FW-450 chemical gametocide.* Rohm and Haas Co., Washington square, Philadelphia 5, Pa.

Artschwager, E. 1942. Colchicine-induced tetraploidy in sugar beets. *Proc. Am. Soc. Sugarbeet Tech.* 296-303.

Avery, G.S. (Jr) and Johnson, E.B. 1947. *Hormones and Harticulture.* McGraw Hill, New York and London, pp. 326.

Barr, C.G. and Newcomer, E.H. 1943. Physiological aspects of tetraploidy in cabbage. *J. agric. Res.* **67** : 329-36.

Blakeslee, A.F. and Avery, A.G. 1937. Methods of inducing doubling of chromosomes in plants by treatment with Colchicine. *J. Hered.* **28** : 393-412.

Brandes, G.A. 1958. *Consideration for further investigation.* 11th Annual Cotton Improvement Conference. Rohm and Haas Co., Philadelphia 5, Pa.

Bringhurst, R.S. 1956. Colchicine-induced polyploidy in the avocade. *Genetics* **41** : 636.

Brock, R.D. 1954. Hormone-induced pear-apple hybrids. *Heredity* **8** : 421.

Burrell, P.C. and Whitaker, T.W. 1939-1940. The effect of indol acetic acid on fruit setting in musk-melons. *Proc. Am. Soc. hort. Sci.* **37** : 829-30.

Chopra, V.L., Jain, S.K. and Swaminathan, M.S. 1960. Studies on the chemical induction of male sterility in some crop plants. *Indian J. Genet.* **20** : 188-99.

Choudhury, B. and George, P.V. 1962. Preliminary trials on the induction of male sterility in brinjal. *Indian J. Hort.* **19** : 140-42.

Crane, M.B. 1941. New blackberries. *Gardening* **63** : 561.

———— and Marks, E. 1952. Pear-apple hybrids. *Nature, Lond.* **170** : 1017.

Darrow, G.M. 1949. Polyploidy in fruit improvement. *Proc. Am. Soc. hort. Sci.* **54** : 523-32.

Dereskevicus, K. 1956. The use of colchicine in tomato breeding. *Bot. Zurnal* **41** : 1462-86. (Russian)

Dermen, H. 1952. Polyploidy in the apple found seven years after colchicine treatment. *J. Hered.* **43** : 7-8.

———— 1954. Colchiploidy in grapes. *ibid.* **45** : 159-72.

———— and Darrow, G.M. 1938. Colchicine-induced tetraploid and 16-ploid strawberries. *Proc. Am. Soc. hort. Sci.* **36** : 300-01.

Dermen, H. and Bain, H.F. 1941. Periclinial and total polyploidy in cranberries induced by colchicine. *ibid.* **38** : 400.

———— and ——— 1944. A general cyto-histological study of colchicine polyploidy in cranberry. *Am. J. Bot.* **31** : 451-63.

Eigste, O.J. 1938. A cytological study of colchicine effects in the induction of polyploidy in plants. *Proc. natn. Acad. Sci. India* **24** : 56-63.

Emsweller, S.L. and Brierley, P. 1940. Colchicine-induced tetraploidy in *Lilium. J. Hered.* **31** : 223-30.

––––– and Rutlle, N.D. 1941. Induced polyploidy in floriculture. *Amer. Naturalist.* **75** : 310-26.

––––– and Stuart, N.W. 1948. Use of growth regulating substances to overcome incompatibilities in *Lilium. Proc. Am. Soc. hort. Sci.* **51** : 581-89.

Gavandan, P., Gavandan, N. and Durard, J. 1938. Surla similitude' Laction de L' acenaphtene et de la colchicine daus I inhibition de la caryocinese. *C. r. Soc. biol. Paris.* **129** : 559-62. (*fide* Avery *et al.*, 1947).

Hawthorne, P.L. 1944. A polyploid watermelon. *Proc. Am. Soc. hort. Sci.* **45** : 348.

Hempbill (1959). Rohm and Hass Co., Philadelphia 5, Pa.

Hensz, R.A. and Mohr, H.C. 1960. Functional male sterility in watermelon induced by chemical treatment. *ibid.* **74** : 552-54.

Hofmeyr, J.D.J. and Elden, H.V. 1942. Tetraploidy in *Carica papaya* induced by colchicine. *South Afr. J. Sci.* **38** : 181-85.

Hull, J.W. and Britton, D.M. 1958. Development of colchicine-induced and natural polyploid breeding lines in genus *Rubus. Bull. Md. Agric. Exp. Stn* No. A-91, pp. 63.

Islam, A.S. 1953. A preliminary report on the colchicine-induced tetraploids of *Annona squamosa. Curr. Sci.* **22** : 118-20.

Iyer, C.P.A. and Randhawa, G.S. 1965. Chemical induction of pollen sterility in grapes. *ibid.* **34** : 411-12.

––––– 1966. Induction of pollen sterility in grapes (*Vitis vinifera*). *Vitis* **5** : 433-45.

Janki Ammal, E.K. 1951. Chromosomes and horticulture tetraploids in guava. *J. R. hort. Soc.* **76** : 236-39.

Johnstone, F.E. (Jr) 1939. Chromosome doubling in potatoes induced by colchicine treatment. *Am. Potato J.* **16** : 288-300.

Jorgensen, C.A. 1928. The experimental formation of heteroploid plants in genus *Solanum. J. Genet.* **19** : 133-211.

Karpechenko, G.D. 1937. Experimental production of tetraploid hybrids, *Brassica oleracea* L.×*B. carinata* Ab-Braum. *Bull. appl. Genet. & Pl. Series II.* **7** : 53-68.

Kerns, K.R. and Collins, J.L. 1947. Chimeras in the pineapple-colchicine-induced tetraploids and diploid-tetraploids in the cayenne variety. *J. Hered.* **38** : 323-30.

Kluge, K. 1954. On the breeding polyploid everbearing strawberry varieties. *Arch. Garteng.* **2** : 201-06.

Kostoff, D. 1938. Polyploid plants produced by colchicine and acenaphthene. *Curr. Sci.* **7** : 108-10.

Lamm, R. 1943. Notes on an octaploid *Solanum panal* plant. *Hereditas* **29** : 193-95.

Levan, A. 1939. Tetraploidy and octaploidy induced by colchicine in diploid petunia. *ibid.* **25** : 109-31.

Lippert, L.F. and Hall, M.O. 1961. Gametocidal action of FW-450 on cantaloupe. *Proc. Am. Soc. hort. Sci.* **78** : 319-23.

Lindstrom, E.W. and Koos, K. 1931. Cytogenetic investigations of a haploid tomato and its diploid and tetraploid progeny. *Am. J. Bot.* **18** : 398-410.

Mehlquist, G.A.L., Blodgett, C.O. and Bruscia, L. 1943. Colchicine-induced tetraploidy in *Delphinium cardinale. J. Hered.* **34** : 187-92.

Miwa, T. 1951. On pollination, fertilization phenomena and problems connected with fruit drop in the Hyuganatsu mandarin *Miyazaki Daigaku Jiho* (*Shizen-kagaku*) *Bull. Miyazaki. Univ.* (*Nat. Sci*). No. 2, pp. 2 (Japanese). (*Plant Br. Abstr.* **28** : 2158).

Moore, R.H. 1958. Several effects of MH of plants. *Science* **112** : 53.

Nakamura, N. 1954. Studies on male sterility in the onion. I. Cytological studies of anthers of male sterile plants. *Rep. Hygo. Univ. Agric. Gec. Agric.* **1** : 118-22 (Japanese).

––––– and Terabun, M. 1955. Studies on artificial male sterility. II. Male sterility induced in the cucumber by application of a chemical. *ibid.* **2** : 44-46.

Nayland, 1959. Rohm and Hass Co., Philadelphia 5, Pa.

Noble, B.R. and Ruttle, M.L. 1938. The cytological and genetical significance of colchicine. *J. Hered.* **29** : 3-9.

–––––. Colchicine and its place in fruit breeding. *New York Agric. Exp. Stn* (*Geneva*) *Circ.* **183** : 1-19.

Newcomer, E.H. 1941. A colchicine-induced homozygous tomato obtained through doubling clonal haploids. *Proc. Am. Soc. hort. Sci.* **38** : 610-12.

––––– A Colchicine-induced tetraploid cosmos. *J. Hered.* **32** : 161-64.

––––– A Colchicine-induced tetraploid cabbage. *Am. Nat.* **75** : 620.

––––– 1943. An F-2 Colchicine-induced tetraploid cabbage and some comparisons with its diploid progenitor. *J. Elisha Mitchell Scient. Soc.* **59** : 69-72.

Olden, E.J. 1954. Giant pollen grains in fruit trees from colchicine treatment in vaccum. *Hereditas* **40** : 526-29. (Abst).

––––– 1958. Reports of current work. Section II. Stone fruits, root-stocks, strawberries and hazel, pp. 12-15.

Olmo, H.P. 1952. Breeding tetraploid grapes. *Proc. Am. Soc. hort. Sci.* **59** : 285-90.

Patel, G.L. and Olmo, H.P. 1956. Induction of polyploidy in the sterile F-1 hybrids *Vitis vinifera* and *V. rotundifolia. Phyton* **7** : 63-68.

Peto, F.H. and Boyes, J.W. 1940. Comparison of diploid and triploid sugarbeets. *Can. J. Res. C* **18** : 273-82.

––––– and Hill, K.W. 1942. Colchicine treatments of sugar-beets and the yielding capacity of the resulting polyploids. *Proc. Am. Soc. Sugarbeet Technol.* 287-95.

Putt, E.D. 1959. *Progress report on FW-450, chemical gametocide.* Rohm and Hass Co., Philadelphia 5, Pa.

Rehm, S. 1952. Male sterile plants by chemical treatment. *Nature, Lond.* **170** : 38-39.

Roble, W. and Honma, S. 1959. *Progress report on F-H. 450, chemical gametocide.* Rohm and Haas Co., Philadelphia 5, Pa.

Rogers, W.S. 1954. Annual Report of the East Malling Research Station, 1954. I. *Pomology* pp. 23-29.

Sansome, F.W. and Zilva, S.S. 1933. Polyploidy and vitamin C. *Biochem. J.* **27** : 1935-41.

—— 1936. Polyploidy and Vitamin C. *ibid.* **30** : 54-56.

Shifriss, O. 1942. Polyploid in genus *Cucumis*. *J. Hered.* **33** : 144-52.

Shimamura, T. 1938. Experiments of the treatment of tomatoes with colchicine solution. *Japan J. Genet.* **14** : 304-08.

Sikka, S.M. 1958. Breeding of fruit plants in India. *Indian J. Hort.* **15** (1) : 10-18.

Singh, R.N. 1953. Colchicine-induced polyploidy in *Papaya*. *Sci. & Cult.* **19** : 44.

Stout, A.B. 1938. The genetics of incompatibilities in homomorphic flowering plants. *Bot. Rev.* **4** : 275-369.

—— and Chandler, C. 1941. Change from self-incompatibility to self-compatibility accompanying change from diploidy to tetraploidy. *Science* **94** : 118.

—— 1942. Hereditary transmission of induced tetraploidy and compatibility in fertilization. *ibid.* **96** : 257-58.

Thompson, R.C. and Kosar, W.F. 1938. Polyploidy in lettuce induced by colchicine. *Proc. Am. Soc. hort. Sci.* **36** : 641-44.

Tozyo Tojo, I. 1954. Chromosome numbers in mulberries treated with colchicine. Nihru Sanshigaker Zasshi. *Jap. J. Seric. Sci.* **23** : 278 (Japanese). *Pl. Breed. Abstr.* **26** : 1752).

Waldo, G.F. and Darrow, G.M. 1948. Origin of the logan and the mammoth blackberries. *J. Hered.* **39** : 99-107.

Walkof, C. 1958. *Progress report on FH-450, chemical gametocide.* Rohm and Haas, Philedephia 5, Pa.

Wester, R.E. and Marth, P.C. 1949. Some effects of a growth regulator mixture in controlled cross-pollination of Lima Bean. *Proc. Am. Soc. hort. Sci.* **53** : 315-18.

Wit, P. 1960. Chemically induced male sterility. A new tool in plant breeding. *Euphytica* **9** (1) : 1-9.

Witkus, E.R. and Berger, C.A. 1944. Vera/mic, a new-polyploidy-inducing agent. *J. Hered.* **35** : 131-33.

Wittwer, S.H. and Hillyer, I.G. 1954. Chemical induction of male sterility in cucurbits. *Science* **120** : 893-94.

CHAPTER VII

Bradley, R.H. and Dean, L.L. 1949. Sprout inhibition of non-dormant chippewa potatoes. *Am. Potato J.* **26** : 279-87.

Cifferri, R. 1953. Prevention of sprouting in potato and onion by the use of maleic hydrazide. *Humus* 9(8) : 13-14.

Dallyn, S. and Smith, O. 1952. Effects of application of growth substances on sprouting of carrot, turnips and onions in storage. *Bot. Gaz.* **113** : 362-66.

Denny, F.E. 1942. Effect of the vapour of the methyl ester of L-NAA on the sprouting and the sugar content of potato tubers. *Contrb. Boyce Thomson Inst. Pl. Res.* **12** : 253-68.

—— 1945. Further tests of the use of the methyl ester of α-NAA for inhibiting sprouting of potato tubers. *ibid.* **14** : 15-20.

Ellison, J.H. and Smith, O. 1949. Effect of spraying a sprout inhibitor on potato plants in the field. *Proc. Am. Soc. hort. Sci.* **51** : 397-400.

—— and Cunningham, H.S. 1953. Effect of sprout inhibitors on the incidence of *Fusarium*, dry rot and sprouting of potato tubers. *Am. Potato J.* **30**(1) : 10-14.

Elmer, O.H. 1936. Growth inhibition in the potato caused by a gas emanting from apples. *J. Agric. Res.* **52** : 609-26.

Emilson, B., Lillieroth, C.G. and Nilsson, R. 1952. The control of sprouting in stored ware potatoes. II. Trials during the storage seasons 1949-50 and 1950-51. *Jl R. Swedish Acad. Agric.* **90** : 421-49.

Gandavillas, H. and Nyland, R.E. 1949. Further studies on the influence of sprout inhibiting and sprout inducing treatment on the growth and yield of potato. *Am. Potato J.* **26** : 7-16.

Garay, O.A. and Pasquale, D.R. 1952. Primaros resultados deles ensayos sobre inhibition de brotaction en papa (first results of experiments on the prevention of sprouting in potato). *Idia.* **5** : 49.

Guthrie, J.D. 1938. Inducing dormancy in potato tubers with potassium naphthaleneacetic acid and breaking it with ethylene chlorohydrin. *Science* **88** : 36.

Humberg, T. 1952. The significance of the acid growth inhibiting substances for the rest period of potato tubers. *Pl. Physiol.* **5** : 115-29.

Isenberg, F.M.R. 1951. The effect of M.H. on certain dehydrogenases in tissues of onion plants. *Science* **113** : 58-60.

Kryut, W. and Valdestra, H. 1951. Potato sprout inhibition by alpha (alkoxymethyl) naphthalenes. Researches on plant growth regulators. XVIII. *Landbouwk, Tijdschr.* **63** : 398-403. (*Hort. Abst.* **22**(3) : 2763.

Marth, P.C. and Schultz, E.S. 1952. A new sprout inhibitor for potato tubers. *Am. Potato J.* **29** (1) : 268-72.

Rehm, S. 1954. The storage of onions and influence of MH on storage quality. *Fmg S. Afr.* **29** : 581-82.

Sawyer, R.L. and Dallyn, S.L. 1956. Vapourised chemical inhibitors and irradiation —two new methods of sprout control for tubers and bulb crops. *Proc. Am. Soc. hort. Sci.* **67** : 514-21.

Schoene, D.L. and Hoffman, O.L. 1949. Maleic hydrazide—a unique growth regulant. *Science* 109-588.

Smith, O., Baeza, M.A. and Ellison, J.H. 1947. Response of potato plants to spray applications of calcium growth-regulating substances. *Bot. Gaz.* **108** : 421-31

Smith, O, Ellison, J.H. and McGoldrick, F. 1949. Growth of potato sprouts retarded by 2,4,5-T. *Science* **109** : 66-68.

Thomes, J.E. and Riker, A.J. 1945. Sprouting of, potatoes inhibited by plant hormones. *Am. Potato J.* **22** : 104-13

Wittwer, S H and Paterson, D.R. 1951. Inhibition of sprouting and reduction of storage losses in onions, potatoes and sugarbeets and vegetable root crops by spraying plant in field with maleic hydrazide. *Q. Bull. Mich. agric. Exp. Stn* 34(1) : 3-8

Wittwer, S.H. and Sharma, R.C. 1950 The control of storage sprouting in onion by pre-harvest foliage sprays of maleic hydrazide *Science* **112** : 597-98.

CHAPTER VIII

Abbott, D.L. and Luckwill, L C. 1952. Parthenocarpy. *N A.A.S. Q. Rev.* **13**(56) : 162-67.

Balasubramanyam, V.R. and Rangaswami, G. 1959. Parthenocarpy in guava induced by pollen hormone. *Curr. Sci.* **28** : 413-15.

Baskaya, M. and Crane, J.C. 1950. Comparative histology of naturally parthenocarpic, hormone-induced parthenocarpic and caprified fig syconia. *Bot. Gaz.* **111** : 395-413.

Basso, M. 1960. Contribute allo studio delle cultivar defico delle provincea di Livorne (A contribution to the study of fig varieties. in the Leghorn province). *Riv. Ortoflorofrutlic* **44** : 194-208.

Batjer, L.P. and Uota, M. 1951. Effect of 2,4,5-T propionic acid sprays on fruit set in pears and apples. *Proc. Am. Soc. hort. Sci.* **58** : 33-36.

Beal, J.M. 1943. Histological studies on parthenocarpic fruits of *Lilium regale* induced by growth substances. *Bot. Gaz.* **105**(1) : 25-34.

Bentlay, T.A. and Bickle, A.S. 1952. Studies on plant growth hormones. II. Further biological properties of 3-indoly-lacetonitrile. *J. exp. Bot.* **3** : 406-23.

Blondeau, R. and Crane, J.C. 1948. Early maturation of calimyrna fig fruits by means of synthetic hormones sprays. *Science* **108** : 719-20.

——— and ——— 1950. Further studies on the chemical induction of parthenocarpy in the calimyrna fig. *Pl. Physiol.* **25** 158-68.

Bradley, M.V. and Crane, J.C. 1962. Cell division and enlargement in mesocarp pareneyma of gibberellin-induced parthenocarpic peaches. *Bot. Gaz.* **123** : 243-46.

Bredermann, H. 1951. Parthenocarpy as the case of badly shaped pears. *Nactr. Bl. Dtsch. Pftsch. Dienst. Braunschweig* **3** : 57.

Burkholder, C.L. and McCown, M. 1940. Effect of loring and of naphthylantic acid and amide spray upon fruit set and of the spray upon preharvest fruit. *Proc. Am. Soc. hort. Sci.* **38** : 117-20.

Clark, H.E. and Kerns, K.R. 1943. Effect of growth regulating substances on a parthenocarpic fruit. *Bot. Gaz.* **104** : 639-44.

Condil, J.J. 1919. The kaki or oriental persimen. *Univ. Calif. agric. Exp. Stn Bull.* 316.

Coombe, B.G. 1960. Relationships of growth and development to changes in sugars, auxins and gibberellins in fruits of seeded and seedless varieties of *Vitis vinifera*. *Pl. Physiol.* **35** : 241-50.

Crane, J.C. 1952. Growth regulator specificity in relation to ovary wall development in fig *Science* **115** : 238-39.

———, 1953. 2,4,5-T on apricot. *Calif. Agric.* 7(3) 15.

——— and Blondeau, R. 1949. The use of growth regulating chemicals to induce parthenocarpic fruits in the calimyrna fig. *Pl. Physiol.* **24** : 44-54.

Crane, J.C. and Blondeau, R. 1949. Controlled growth of fig fruits by synthetic hormone application. *Proc. Am. Soc. hort. Sci.* **54** : 102-08.

——— and Baskaya, M. 1951. Differential ovary wall development in fruit-lets of hormone-induced parthenocarpic calimyrna fig syconia. *ibid.* **56** : 83-5.

——— and Blundeau, R. 1951. Hormone-induced parthenocarpy in the calimyrna fig and a comparison of parthenocarpic and caprified syconia. *Pl. Physiol.* **26** : 136-45.

——— and Campbell, R.C. 1959. Fruit and vegetable responses of the calimyrna fig to gibberellin. *Proc. 13th Res. Conf. Calif. Fig Inst.* pp. 11-14.

——— Primer, P.E. and Campbell, R.C. 1960. Gibberellin induced parthenocarpy in *Prunus*. *Proc. Am. Soc. hort. Sci.* **75** : 129-37.

———, Rebeiz, C.A. and Campbell, R.C. 1961. Gibberellin-induced parthenocarpy in the J.H. Hale peach and the probable cause of button production. *ibid* **78**: 111-18.

——— and Brooks, R.M. 1952. Growth of apricot fruits as influenced by 2,4,5 trichlorophenoxyacetic acid application. *ibid.* **59** : 218-24.

Davison, R.M. 1960. Fruit setting of apples using gibberellic acid. *Nature, Lond.* **188** : 681-82.

Dennis, F.G. (Jr) 1962. Induction of parthenocarpy in the apple and stimulation of fruit growth *in vivo* and *in vitro*. *Diss. Abstr.* **22** : 2158 being order No. 61-5195 of pp. 243.

Dhuria, H.S. 1962. *Studies on Fruit Set and Fruit Drop in Citrus with Special Reference to Grapefruit and Sweet Lime.* Thesis submitted for the degree of Doctor of Philosophy to the faculty of P.G. School, IARI, New Delhi.

Dikshit, N.N. 1956. Some aspects of parthenocarpy in fruit plants. *South Indian Hort.* 4 (3) : 64-69.

——— 1957. Parthenocarpy in some fruit plants. Part II. Review of literature on parthenocarpy induced by growth substances and its effects on fruits and plants. *Mysore agric. J.* **32** : 162-78.

——— 1958. Hormone-induced parthenocarpy in *Annona squamosa* Linn., custard apple. *Indian J. Pl. Physiol.* **1** : 54-57.

——— 1959. Initial stages of parthenocarpy in custard apple (*Annona squamosa* Linn.) following treatment with 2,4,5-trichlorophenoxy acetic acid. *Sci. & Cult.* **24** : 381-82.

Dollfus, H. 1936. Wuchsstoffstudien. *Planta.* **25** : 1-21.

Fitting, H. 1909. Die Beeinflussung der Orchideenbluten durch die Bestaubung and durch andere Umstande. *Zeitschr Bot.* **1** : 1-86.

Gardner, F.E. and Kraus, E.J. 1939. Histological comparison of the fruits developed parthenocarpically and following pollination. *Bot. Gaz.* **99** : 355-96.

——— and Marth, P.C. 1937. Parthenocarpic fruits induced by spraying with growth-promoting compounds. *ibid.* **99** : 184-95.

Gonzalez Alonson, M. 1955. Induction of parthenocarpy in Cucurbitaceae and particularly in *Citrullus vulgaris*. *Famacognoisia* : 379-95.

Gorter, C.J. and Visser, T. 1958. Parthenocarpy of pears and apples. *J. hort. Sci.* **33** : 217-27.

Greene, L. 1943. Growth regulators and fruit set with starking apples. *Proc. Am. Soc. hort. Sci.* **42** : 149-50.

Griggs, W.H., Iwakiri, B.T. and Detar, J.E. 1951. The effect of 2,4,5-Trichlorophenoxy propionic acid applied during the bloom period on the fruit set of several pear varieties and the shape, size, stem length, seed content, and storage of Bartlett pears. *ibid.* **58** : 37-45.

Gustafson, F.G. 1936. Inducement of fruit development by growth-promoting chemicals. *Proc. natn. Acad. Sci. U.S.A.* **22** (11) : 628-36.

—— 1937. Parthenocarpy induced by pollen extracts. *Am. J. Bot.* **24** : 102-7.

—— 1938. Further studies on artificial parthenocarpy. *ibid.* **25** : 237-44.

—— 1938. Induced parthenocarpy. *Bot. Gaz.* **99** : 840-44.

—— 1939. Auxin distribution in fruits and its significance in fruit development. *Am. J. Bot.* **26** : 189-93.

—— 1939. The cause of natural parthenocarpy. *Am. J. Bot.* **26** : 135-38.

—— 1940. Parthenocarpic and normal fruits compared as to percentage setting and size. *Bot. Gaz.* **102** : 260-66.

—— 1941. Probable causes for the difference in facility of producing parthenocarpic fruits in different plants. *Proc. Am. Soc. hort. Sci.* **38** : 479-81.

—— 1942. B-naphthoxyacetic acid as an inductor of parthenocarpy in tomatoes. *ibid.* **40** : 387-89.

—— 1942. Parthenocarpy : Natural and artificial. *Bot. Rev.* **8** (9) : 599-654.

Hamner, C.L., Schomer, H.A. and Marth, P.C. 1944. Application of growth-regulating substances in aerosal form with special reference to fruit set in tomato. *Bot. Gaz.* **106** : 108-23.

Harris, R.W. and Hansen, C.J. 1955. The effect of growth regulators on the drop of French (Agen) prunes. *Proc. Am. Soc. hort. Sci.* **66** : 79-83.

Hartley, C P. 1902. Injurious effect of premature pollination and setting of fruits without pollination. *U.S. Dep. Agric. Bull. Pl. Ind. Bull.* 22.

Hield, H.Z. 1961. Avocado fruit set. *Calif. Citrogr.* **46** : 115-17.

Hoffmann, O.L. and Smith, A.E. 1949. A new group of plant growth regulators. *Science* **109** : 588.

Howlett, F.S. 1941. Effect of indolebutyric acid upon tomato fruit set and development. *Proc. Am. Soc. hort. Sci.* **39** : 217-27.

—— and Marth, P.C. 1941. Aërosal application of growth-regulating substances to the greenhouse tomatoes. **48** : 458-74.

Jackson, G.A.D. and Prosser, M.V. 1959. The induction of parthenocarpic development in *Rosa* by auxins and gibberellic acid. *Naturwiss.* **46** : 407.

Kononov, A.V. 1960. The effect of gibberellin on vine inflorescences. *Priroda* **49** (11) : 104-5.

Laibach, F. 1932. Pollenhormon und Wuchsstoff. *Ber. dtsch. bot. Ges.* **50** : 383-90.

Leopold, A.C. 1960. *Auxins and Plant Growth.* Univ. Calif. Press, Berkley, pp. 215-30.

—— 1962. The role of growth substances in flowers and fruits. *Can J. Bot.* **40** : 745-755.

Lewis, D. 1946. Chemical control of fruit formation. *J. Pomol.* **22** : 175-83.

Luckwill, L.C. 1948. The hormone content of the seed in relation to endosperm development and fruit drop in apple. *J. hort. Sci.* **24** : 32-44.

—— 1946. Fruit setting sprays for tomato. *Agriculture* **53** : 262-5.

—— 1957. Studies of fruit development in relation to plant hormones. IV. Acid auxins and growth inhibitors in leaves and fruits of the apple. *J. hort. Sci.* **31** : 18-33.

—— 1960. Fruit growth in relation to internal and external chemical stimuli. pp. 223-251. In (Ed. Dorothea Rudnick) cell organism and Millieu, 17th growth symposium. Ronald Press. N.Y.

—— 1959. Factors Controlling the growth and form of fruits. *J. Linn. Soc.,* (*Bot.*) **56** : 294-302.

—— 1959. Gibberellic acid can save pears. *Grower* **52** : 451-53.

—— 1964. The effect of gibberellic acid on fruit set in apples and pears. *A.R. Long Ashton agric. hort. Res. Stn 1959, 1960*, pp. 59-64.

Massart, J. 1902. Surl a pollination sans fecondation. *Bull. Jard. Bot. Brux.* **1** : 89.

Meyer, B.S., and Anderson, D.B. 1956. *Plant Physiology.* D. Van Nostrand Co. Inc. New York, pp. 659-61.

Modlibowska, I. 1960, 1961. Stimulation of fruit development in frost damaged pears. *A.R.E. Malling Res. Stn A.* **44** : 46-48.

Mori, H. 1947. On parthenocarpy in *Cucurbita moschata* Duch induced by growth-promoting substarces and their effectiveness for preventing fruit abscission. (*Hort. Abstr.* **20** : 851). *J. Hort. Assoc. Japan* **16** : 154-60.

Muir, R.M. 1942. Growth harmones as related to the setting and development of fruit in *Nicotiana tabacum.* *Am. J. Bot.* **29** : 716-20.

Nitsch, J.P. 1952. Plant hormones in the development of fruits. *Q. Rev. Biol.* **27** : 33-57.

—— 1956. Methods for investigation of natural auxin and growth inhibitors. pp. 3 in (ed. Wain and Wightman). *The Chemistry and Mode of Action of Plant Growth Substances.* Butterworths Scientific Publication, London.

Nixon, R.W. and Gardner, F.E. 1939. Effect of certain growth substances on inflorescences of dates. *Bot. Gaz.* **100** : 868-71.

Noll, F. 1952. Fruchtbildung ohne vorausgegangene Bestaubung (Parthemokarpic) bei der gurke S-B niederrhein. *Ges. Nat. U. Heilk* (*Bonn*). 149-162.

Osborne, D.J. 1949. Attempts to produce parthenocarpic pears with growth substances. *Ann. appl. Biol.* **36** : 551-53.

—— and Wain, R.L. 1951. Studies on plant growth regulating substance. III. The Production of parthenocarpic pomaceous fruits by chemical treatment. *J. hort. Sci.* **26** : 317-27.

Pearse, H.L. 1948. *Growth Substances and Their Practical Importance in Horticulture.* Tech. Comm. No. 20. Commonwealth Bureau of Horticulture and Plantation Crops, East Malling Kent (U.K.).

Phinney, B.O., West, C.A., Ritzel, M. and Neeley, P.M. 1957. Evidence for gibberellin-like substances from flowering plants. *Proc. natn. Acad. Sci. Washington* **43** : 398-404.

Pomeroy, C.S. and Aldrich, W.W. 1943. Set of citrus fruits in relation to applications of certain growth substances. *Proc. Am. Soc. hort. Sci.* **42** : 146-48.

Pratt, C. and Shanlis, N.J. 1961. Gibberellin-induced parthenocarpy in grapes. *ibid.* **77**: 322-30.

Primer, P.E. and Crane, J.C. 1957. Growth regulator induced parthenocarpy in apricots. *ibid.* **70** : 121-24.

Rabeiz, C.A. and Crane, J.C. 1961. Growth regulator induced parthenocarpy in the Bing Cherry. *ibid.* **78** : 59-75.

Randhawa, G.S. and Thompson, R.C. 1948. Effect of hormone sprays on yield of snap beans. *ibid.* **52** : 449-52.

Randhawa, G.S., Dhuria, H.S. and Nair, P.K.P. (1964). A note of gibberellin-induced parthenocarpy in citrus. *Indian J. Hort.* **21** (2) : 172-72.

Rangaswami, G. and Kaliaperumal, T.T. 1960. The presence of indole-like compounds in parthenocarpic guava. *Curr. Sci.* **29** : 485-86.

Redemann, C.T., Wittwer, S.H. and Sell, H.M. 1950. Precautions in the use of lanolin as an assay diluent for plant growth substances. *Pl. Physiol.* **25** : 356-58.

------ 1951. Characterization of indoleacetic acid and its esters. *J. Am. Chem. Soc.* 73 : 29-57.

Sereisky, A.S. 1938. The effect of hormones on fruit formation and the problems of experimental parthenocarpy (Russian) Publ. (Zbirnik Prats). *Ukrain Acad. Sci. Kieu.*, pp. 115-27.

Shanmujavelu, K.G. 1962. A preliminary study in the induction of parthenocarpic guava by gibberellic acid. *Indian J. Hort.* **19** : 128-29.

------, Balasubramaniam, M. and Rangaswami, G. 1961. Natural occurrence of auxins in plants. From Abstr. in *Madras agric. J.* **48** (12) : 24.

Soost, R.K. and Burnett, R.H. 1961. Effect of gibberellin on yield and fruit characteristics of Clementine mandarin. *Proc. Am. Soc. hort. Sci.* **77** : 194-201.

------ 1958. Gibberellic acid on mandarin. *Calif. agric.* **12** (5) : 5.

Stewart, W.S. and Hield, H.Z. 1951. Effect of growth regulating sprays on fruit set of avocado. *Proc. Am. Soc. hort. Sci.* **58** : 53-56.

Stout, A.B. 1936. Seedlessness in grapes. *Tech. Bull. N.Y. agric. Exp. Stn*, **238**, p. 63.

Strong, M.C. 1941. The effect of various growth promoting chemicals on the production of tomato fruits in the greenhouse. *Q. Bull. Mich. agric. Exp. Stn* **24** : 56-64.

------ 1944. Improvement of greenhouse tomato production by the use of vaporous naphthoxyacetic acid. *Bull. Mich. agric. Exp. Stn* **27** : 225-36.

Swarbrick, T. 1945. Use of growth-promoting substances in the prevention of apple drop following frost. *Nature, Lond.* **156** : 691.

------ 1947. Growth-regulating substances in horticulture. *Jl R. Hort. Sci.* **72** : 313-27, 242-59.

Teaotia, S.S., Pandey, I.C. and Mathur, R.S. 1961. Gibberellin-induced parthenocarpy in guava (*Psidium guajava* L.). *Curr. Sci.* **30** : 312.

Thimann, V.K. 1934. Studies on the growth hormone of plants. VI. The distribution of the growth substances in plant tissues. *J. gen. Physiol.* **18** : 23-34.

Thompson, A.H. 1951. The effect of 2,4,5-TP sprays in delaying the preharvest drop in several apple varieties. *Proc. Am. Soc. hort. Sci.* **58** : 57-64.

Treccani, C.P. 1948. The effect of sodium salt of 2,4-D on the production of tomatoes marrows and watermelons. *Ann. Sper. Agrar.* **2** (N.S.) : 173-99.

Villariba, C.A. and Capinpin, J.M. 1948. Morphogenetic effects of 2,4-D on some crop plants (in the tropics). *Philip. Agric.* **31** : 163-76.

Weaver, R.J. and Williams, W.O. 1950. Response of flowers of black Corinth and fruit of Thomson seedless grapes to applications of plant growth regulators. *Bot. Gaz.* **111** : 477-85.

Went, F.W. 1938. Specific factors other than auxin affecting growth and root formation. *Pl. Physiol.* **13** : 55-80.

Wittwer, S.H. and Bukovac, M.J. 1957. Gibberellin and higher plants. III. Induction of flowering in long day annuals grown under short days. *Q. Bull. Mich. agric. Exp. Stn* **39** : 661-72.

Wong, C.Y. 1940. Progress report on induced parthenocarpy in some horticulture crops. *Proc. Am. Soc. hort. Sci.* **37** : 158-60.

Wood, J.W. and Fontaine, T,D. 1952. Synthetic plant growth regulators III. 2,4-D derivatives of amino acids. *J. org. Chem.* **17** : 891-96.

Woodcock, D. 1947. Isolation of phloridzation from apple seeds. *Nature, Lond.* **159** : 100.

Yasuda, S. 1933. On the behaviour of pollen tubes in the production of seedless fruits caused by interspecific pollination. *Jap. J. Genet.* **8** : 239-44.

------ 1934. The second report on the behaviour of the pollen tubes in the production of seedless fruits caused by interspecific pollination. *ibid.* **9** : 18-24.

------ 1934. Parthenocarpy caused by the stimulus of pollination in some plants of Solanaceae. *Agric. & Hort.* **9** : 647-56.

------, Inaba, T. and Takahashi, Y. 1933. Parthenocarpy caused by the stimulation of pollination in some plants of the Cucurbitaceae. *ibid.* **10** : 1385-90.

Zimmerman, P.W. 1942. Formative influences of growth substances on plants. *Cold Spr. Harb. Symp. Quant. Biol.* **10** : 152-57.

------, and Hitchcock 1939. Responses of plants to growth substances applied as solutions and as vapour. *Contro. Boyce. Thomson. Inst. Pl. Res.* **10**(3) : 363-75.

------ 1941. Formatives effects induced with B-naphthoxyacetic acid. *Ibid.* **12** : 1-14.

------ and Hitchock, A.E. 1942. Substituted phenoxy and benzoic acid growth substances and the relation of structure of physiological activity. *Contrb. Boyce Thomson Inst. Pl. Res.* **12** : 321-43.

CHAPTER IX

Armstrong, J.L. 1958. Research on gibberellins. I. Gibberellin studies on radishes. *Bios.* **20** : 139-41.

Basford, K.H. 1961. Morphogenetic effects of GA on senecio species. *Ann. Bot.* **25** : 99.

Biswas, P.K. and Rogers, M.R. 1963. Effects of gibberellic acid on size and quality of inflorescence in geranium, *Pelargonium hortorum*. *Proc. Am. Soc. hort. Sci.* **82** : 409-93.

------ The effects of different light intensities applied during the night on the growth and development of column stocks (*Mathiola incana*). *ibid.* **82** : 586-88.

Blumenthal, Goldschmidt, S. and Lang, A. 1960. Presence of gibberellin like substance in lettuce seed. *Nature, Lond.* **186** : 815-16.

Brian, P.W. and Hemming, H.G. 1958. Complimentary action of gibberellic acid and auxins in pea internode extension. *Ann. Bot.* **22** : 1-17.

——, Grove, J.F., Hemming, H.G., Mulholland, T.P.C. and Radley, M. 1958. Gibberellic acid part N. The biological activity of allogibberellic acid and its identity with gibberellin B. *Pl. Physiol.* **33** : 329-33.

—— 1959. Effects of gibberellins on plant growth and development. *Biol. Rev.* **34** : 37-84.

—— 1961. Possible use of gibberellins in horticulture. *Scient. Hort.* **15** : 27-36.

Bukovac, M.J. and Wittwer, S.H. 1956. Gibberellic acid and high plants. I. General growth responses. *Q. Bull. Mich. Agric. Exp. Stn.* 39(2) : 307-20.

—— and —— 1957. Gibberellin and higher plants. II. Induction of flowering in biennials. *ibid.* 39(4) : 650-60.

——, Wittwer, S.H. and Teubner, F.G. 1957. Gibberellin and higher plants. VII. Flower formation in the tomato. *ibid.* 40(1) : 207-14.

—— and Cook, J.A. 1960. The effects of preharvest foliar sprays of GA_3 on yield and storage breakdown of cleary. *ibid.* 42(4) : 769-70.

Burk, L.G. and Tro, T.C. 1958. Effect of gibberellin acid on *Nicotiana* plants. *Nature, Lond.* **181** : 1672-73.

Butcher, D.N. and Street, H.B. 1960. The effect of gibberelllin on the growth of excised tomato roots. *J. exp. Bot.* **11** : 206-16.

Chandler, C 1957. The effect of gibberellic acid on germination and pollen tube growth. *Contrb. Boyce Thomson Inst. Pl. Res.* **19** : 215-24.

Chaudhury, B. and Phatak, S.C. 1959. Sex expression and fruit development in cucumber (*Cucumis sativus*) as affected by gibberellins. *Indian J. hort.* **16**(4) : 233-35.

Chhonkar, V.S. and Singh, S.N. 1963. Studies on inorganic nutrition of *bhindi* (*Abelmoschus esculentus* (L.) Moench) in sand culture. *ibid.* **20**(1) : 51-58.

Clore, W.J. 1965. Responses of Delaware grapes to gibberellin. *Proc. Am. Soc. hort. Sci.* **87** : 259-63.

Coggins, C.W. (Jr) *et al* 1953. Navel Orange - rind staining reduced by gibberellin A_3. *ibid.* **82** : 154-57.

—— and Lewis, L.N. 1965. Some physical properties of the Navel Orange rind as related to ripening and to gibberellic acid treatments. *ibid.* **86** : 272-79.

Collins, W.B., Irving, K.H. and Barker, W.G. 1966. Growth substances in the flower bud and developing fruit of *Vaccinium angustifolium*. *Proc. Am. Soc. hort. Sci.* **89** : 243-48.

Coulombe, L.J. and Paquin, R. 1959. Effect of gibberellic acid on plant metabolism. *Can. J. Bot.* **37** : 897-901.

Crane, J.C. 1958. Breaking rest period, inducing parthenocarpy in Calymyrna fig with gibberellins. *Proc. Am. Soc. hort. Sci.* **76** : 139-45.

—— and Grossi, N. 1960. Fruit vegetative responses by Mission Fig with gibberellins. *ibid.* **76** : 139-45.

——, Primer, P.E. and Campbell, R.C. 960. Gibberellin induction parthenocapy in prunes. *ibid.* **75** : 128-37.

Cross, B.E. 1954. Gibberellic acid, Part I. *J. chem. Soc.* 4670-76.

——, Grove, J.F., MacMillan, J. and Mulholland, T.P.C. 1956. Gibberellic acid Part IV. The structures of gibberellic and allogibberic acids and possible structures for gibberellic acid. *Chem. Ind.* : pp. 954-55.

——, Galt, R.H.B. and Hanson, J.R. 1960. Gibberellin A_7 a new fungal gibberellin. *Tetrahedron Letters* (in press).

——, Grove, J.F., McCloskey, P., MacMillan, J., Moffatt, J.S. and Mulholland, T.P.C. 1961. The structures of the fungal gibberellins. *Adv. Chem. Ser.* **28** : 3-17.

Davis, D. and Kalmos, S. 1957. The effect of gibberellin on plant disease. *Pl. Dis. Reptr.* **41** : 890-91.

Dhuria, H.S. and Randhawa, G.S. 1963. Effect of gibberellic acid on germination and pollen tube growth in citrus. *Indian J. Hort.* **20** (3 and 4) : 186-90.

Dostal, R. 1964. Effect of gibberellic acid on the initiation of buds in lilac. *Nature, Lond.* **201** : 843-44.

Frankland, B. and Wareing, P.F. 1960. Effects of GA on hypocotyl growth of lettuce seedlings. *Nature, Lond.* **185** : 255-56.

Galun, E. 1959. Effect of GA_3 and NAA on sex expression and some morphological characters in the cucumber plant. *Phyton* **13** : 1-8.

Gray, R.A. 1957. Alteration of leaf size and shape and other changes caused by gibberellins in plants. *Am. J. Bot.* **44** : (8) : 674-82.

—— 1958. Breaking the dormancy of peach seed and crab grass seeds with gibberellin *Pl. Physiol. Abstr.* **33**.

Griggs, W.H. and Twakari, B.T. 1961. Effect of gibberellic acid and 2,4-D sprays on Bartlett Pears. *Proc. Am. Soc. hort. Sci.* **77** : 73-90.

Harada, H. and Nitsch, J.P. 1959. Flower induction in Japanese chrysanthemum with GA. *Science* **129** : 777-78.

Harrington, J.F. 1960. The use of gibberellic acid to induce bolting and increasing seed yield of light heading lettuce. *Proc. Am. Soc. hort. Sci.* **75** : 276-79.

Hartmair, V. and Hobl, H. 1963. Versuche Zur Gibberellin worlimg aif Reven. (Experiments on the action of gibberellin on vines). *Mitt. Kolsterneu-burg.* Ser. A, **13** A : 124-33.

Hayashi, T. and Murakami, Y. 1958. *Bull. natn. Inst. Agric. Sci.* (Japan) D. No. **7** 159.

Hield, H.Z., Coggins, C.W. and Garber, M.J. 1958. Gibberellin treated on citrus. *Calif Agric.* **12**(5) : 9-11.

Kahn, A., Goss, J.A. and Smith, D.E. 1957. Effect of gibberellin on germination of lettuce seed. *Science* **125** : 645-46.

Kato, J. 1958. Studies on the physiological effect of gibberellin. II. On the interaction of gibberellin with auxins and growth inhibitors. *Physiologia. Pl.* **11** : 10-15.

Kende, H. and Lang, A. 1964. Gibberellins and light inhibition of stem growth in peas. *Pl. Physiol.* 39 : 425-40.

Koffranck, A.M. 1959. The effect of gibberellin by attapulgite clay on the top growth of pea seedlings. *Proc. Kon. Ned. Acad. Wetenset. Amsterdam* Ser. C. **62** : 533-41.

Kononov, A.V. 1960. The effect of gibberellin on vine inflorescences (Russian). *Priroda* 49(11) : 104-05.

Kribben, F.J. 1957. Gibberellinsaure used Blattwabhstum. *Naturwissenshaften* **44** ; 429.

Krishnamurthi, S., Randhawa, G.S. and Singh, J.P. 1959. Effects of gibberellic acid on fruit set, size and quality in Pusa Seedless variety of grapes. (*Vitis vinifera* L.). *Indian J. Hort.* **16** : 1-4.

Kurosawa, E. 1926. Experimental studies on the nature of the substance exerted by "bakanae" fungus. *Trans. Nat. Hist. Soc. Formosa* **16** : 213-27.

Kuse, G. 1958. Necessity of auxin for the growth effect of gibberellin. *Bot. Mag. Tokyo* 77 : 151-59.

Lang, A. 1956. Induction of flower formation in biennial *Hyoscyamus* by treatment with gibberellin. *Die Natwiwiss.* 43 : 234-85.

Leben, C. and Barton, L.V. 1957. Effects of gibberellic acid on growth of kentucky blue grass. *Science* **125** : 494-96.

Lert, P.J. 1959. Gibberellins on chrysanthemum. *Calif. Agric.* **13**(4) : 4.

Lincoln, R.G. and Hamner, K.C. 1958. An effect of gibberellic acid on the flowering of xanthium, a short day plant. *Pl. Physlol.* 33 : 101-04.

Lindstrom, R.S. and Wittwer, S.H. 1957. Gibberellin and higher plants IX. Flowering in geranium. *Q. Bull. Mich. agric. Exp. Stn* **40** : 32-41.

— ——, ——— and Bukovac, M.J. 1957. Gibberellin and higher plants IV. Flowering response of some flower crop. *ibid.* 39(4) : 673-81.

Lippert, L.F., Rappaport, L. and Jimm, H. 1958. Systematic induction of sprouting in white potatoes by foliar applications of gibberellin. *Pl. Physiol.* **33** : 132-33.

Liverman, J.L. and Johnson, S.P. 1957. Control of arrested fruit growth in tomato by gibberellins. *Science* **125** : 1086-87.

Lona, F. 1956. L'acido gibberellico determina la germination dei *Lactuca scariola* in fase di scoto-inbizione. *L'Ateneo Parmense* **27** : 641-44.

——— L' azione dell acido gibberellic sull accrescimento caulinare di talune piante erbacee in candizioni esterne controllate. *Nuovo Giorn. Bot. Italiano* **63** : 61-76.

——— Osservazioni orientative cisea l'effectto dell acido gibberellico sullo Briluppo riproduttivo di olcume longidiurne e brevidiurne. *Aten. Parm.* **27** : 867-75.

———. Recenti esperienze sulla proprieta dell acido gibberellico. *Riv. Int. Agric.* **1**(10-11) : 62-76.

Mac Millan, J. and Suter, P.J. 1958. The occurrence of gibberellin A, in higher plants : isolation from the seeds of runner bean (*P. multiflorus*). *Naturwissenschaften* **45** : 47-47.

———, Seaton, J.C. and Suter, P.J. 1960. The isolation and structure of gibberellin from higher plants. *Abstr. Am. Chem. Soc. Meet. New York*, Sept., 11-16.

Manankov, D.K. 1960. The effect of GA on the fruit formation of varieties of grape with functionally female types flower. *Fiziol. Rast* (Russian, English Translation) **7** : 350-54.

Marcelle, R. and Sironval, C. 1962. Effect of gibberellic acid on flowering of apple trees. *Nature, Lond.* **197** : 405.

——— and ——— 1963. Effect of gibberellic acid on flowering of apple trees. *Nature, Lond.* **197** : 405.

Michel-Wolwertz, M.R. and Sironval, C. 1963. Inhibition of growth and accumulation of B-carotene in carrot roots by gibberellic acid. *Phytochem. Newsl* **2** ; 183-87

Morgan, D.G. and Mees, G.C. 1958. Gibberellic acid and growth of crop plants. *J. agric. Sci.* **50** : 49-59.

Ogawara, K. and Ono, K. 1957. Studies on the germination of lettuce seeds. I. Inducing light sensitivity in non-dormant light in Sensitive lettuce seed (treated with 2,4-D, FAP). *Stud. Inst. Hort. Kyoto* **8** : 106-11.

Paterson, J.B.E. 1967. Gibberellin and gibberellic acid. *N.A.A.S. Q. Rev.* **38** : 139-43.

Paterson, E.E. and Anhder, L.D. 1960. Induction of staminate flowers on gynoecious cucumber with gibberellins. *Science* **181** : 1673-74.

Paul, C.M., William, V.A. and John, W. Michell 1956. Effect of gibberellic acid on growth and development of plants of various genera and species. *Bot. Gaz.* **118**(2) : 106-11.

Phinney, O.B. and West C.A. 1960. Gibberellins as native plant growth regulator. *Ann. Rev. Pl. Physiol.* **111** : 411-32.

Pirone, P.P. 1958. Gibberellin plant growth stimulator. *Gdn. J.N.Y. bot. Gdn* **8** : 42-46.

Proebsting, E.L. (Jr.) and Mills, H.H. 1964. Gibberell in induced hardiness responses in Elberta peach flower buds. *Proc. Am. Soc. hort. Sci.* **85** : 134-40.

Racoff, H. 1963. Treatment of *Camellia* buds with gibberellic acid. *Carolina Comellias* **14**(2), reprint in *Am. Camellia yearle* 1964, 1963, pp. 207-19.

Radley, M. 1956 Occurrence of substances similar to gibberellic acid in higher plants. *Nature, Lond.* **178** : 1070-71.

——— 1958. The distribution of substances similar to gibberellic acid in higher plants. *Ann. Bot.* **22** : 292-307.

——— 1961. Gibberellin-like substances in plants legumes root nodules, sea weed (*Fucus vesiculosus*). *Nature, Lond.* **191** : 684-85.

——— 1963. Gibberellin content of spinach in relation to photoperiod, *Ann. Bot. Lond.* **27** : 273-77.

Randhawa, G.S. and Singh, J.P. 1959. Growth response of citrus root-stocks to GA. *Indian J. Hort.* **16** : 76-78.

———, ——— and Dhuria, H.S. 1959. Effect of gibberellic acid, 2,4-D, 2,4,5-T in fruit set, drop and total yield in sweet lime (*Citrus limettioides*). *Indian J. Hort.* **16** : 206-09.

——— and Sharma, B.B. 1962. Effect of plant regulators on fruit set, drop and quality of sweet oranges (*Citrus sinensis* Osbeck). *ibid.* 19 (3&4) : 83-91.

———, Dhuria, H.S. and Nair, P.K.R. 1964. A note on gibberellin induced parthenocarpy in citurs. *ibid.* **21** (2) : 171-72.

——— and ——— 1965. Effect of plant regulators on fruit set and fruit drop in citrus III. Sweet lime (*Citrus limettioides* Tanaka). *ibid.* **22** (2) : 131-39.

Rao, S.N. and Rao, C.H.S. 1963. Studies on the effect of gibberellic acid and some other growth regulators on *phalsa* (*Grewia asiatica* L.). *S. Indian Hort.* **11** : 31-33.

——— and Rao, P.B. 1963. A note on the effect of gibberellic acid on fruit development in *Hibiscus rosa-sinensis* L. *ibid.* **11** : 37-38.

———, Ch. Subha Rao, and Rao, P.B. 1963. Effects of gibberellic acid on loquat (*Eriobotrya japonica*). *J. hort. Sci.* **38** : 1-3.

RAPPAPORT, L. 1956. Growth regulating metabolites. *Calif. Agric.* **10** : 4.

——— 1958. Effect of gibberellic acid on genetic characters in two tomato lines. *Bot. Gaz.* **121** : 114-18.

——— 1957. Effect of gibberellin on growth, flowering and fruit set of Early pale tomato. *Pl. Physiol.* **32** : 440-41.

——— 1960. Effect of temperature and gibberellin on the growth of tomato fruits. *Naturwissenschaften* 47 : 285.

RICHARDSON, S.D. 1958. Radicle elongation of *Pseudolraga menginessi* in relation to light and gibberellic acid. *Nature, Lond.* **181** : 890-91.

SACHS, R.M. and LANG, A. 1957. Effects of gibberellin on cell division in *Hyoscyamus. Science* **125** : 1144-45.

———, ———, BEETZ, C.F. and ROACH, J. 1960. *Am. J. Bot.* **47** : 260-66.

——— and ——— 1961. Shoot histogenesis and the subapical meristem : the action of gibberellic acid, Amo-1618, and maleic hydrazide in plant Growth Regulation (Ed. R.M. Klein) *4th International Conference on Plant Growth Regulation.* Iowa State University Press, U.S.A.

SHAULLIS, N. 1959. *N.Y. Farm Research* **25** : 11.

SINGH, J.P. and RANDHAWA, G.S. 1959. Effect of gibberellic acid and para-chlorophenoxyacetic acid on growth and fruitfullness in strawberry. *Indian J. Hort.* **16** : 14-17.

———, ——— and JAIN, N.L. 1960. Response of strawberry to gibberellic acid. *Ibid.* 17(1) : 21-30.

SINGH, K. KIRPAL, NIJJAR, G.S. and SINHA, T.N. 1966. Effect of GA and Thiourea on germination of peach seed. *J. Res.* 3(2) : 146-51.

SINK, K.C. and WALKER, D.E. 1964. Effects of photoperiod and gibberellin on growth and flowering azaleas. *Proc. Am. Soc. hort. Sci.* **84** : 564-69.

SMITH, C.R., SOCZEK, Z. and COLLINS, W.B. 1961. Flowering and fruiting of strawberries in relation to gibberellin. *Adv. Chem. Ser.* 28.

SOOST, R.K. 1959. Effects of gibberellic acid on genetic characters in two tomato lines. *Bot. Gaz.* **121** : 114-18.

——— and BURNETT, R.H. 1961. Effect of GA on yield and fruit characteristics of clementine mandarin. *Proc. Am. Soc. hort. Sci.* 77 : 194-201.

STEWART, W.S., CHING, F.T. and HALSEY, D.D. 1957. Effects of gibberellic acid sprays on Thompson Seedless Grapes. *Lazaa Leaves* **7** : 80.

STODOLA, F.H., RAPER, K.B., FENNELL, D.T., CONWAY, H.F., SOHNS, W.E., LANGFORD, C.T. and JACKSON, R.W. 1955. The microbiological production of gibberellins A and X. *Arch. Biochem. Biophys.* **54** : 240-45.

STOWE, B.B. and YAMAKI, T. 1957. The history and physiological action of gibberellins. *Annu. Rev. Pl. Physiol.* **8** : 181-216.

——— and ——— 1959. Gibberellins stimulants of plant growth. *Science* **129** : 807-16.

STUART, N.W. and CATHEY, H.M. 1961. Applied aspects of the gibberellic acid on nursery stocks of mango (*Mangifera indica* Linn.) and *Citrus* spp. *S. Indian Hort.* **11** : 18-30.

TIMM, H. and RAPPAPORT, L. 1960. Spraying plant growth and tuber production as affected by chemical treatment of white potato and pieces. II. Effect of temperature and time of treatment with GA. *Am. J. Bot.* **37** : 357-65.

TURNER, J.N. 1963. Application of gibberellic acid to strawberry plants at different stages of development. *Nature, Lond.* **197** : 95-96.

VENKATARATNAM, L. 1961. Effect of GA on Anab-e-Shahi grape. *Fourth hort. Res. Workers Conf.* Sub. No. 3(3).

WEAVER, R.J. 1958. Effect of GA on fruit set and berry enlargement in seedless grapes of *Vitis vinifera. Nature, Lond.* **181** : 851-52.

——— 1961. Growth of grapes in relation to gibberellin. *Adv. Chem. Ser.* No. 28.

——— and MC CUNE 1958. Gibberellin tested on grapes. *Calif. Agric.* 12(2) : 6-7.

——— 1959. Effect of gibberellin on seeded *Vitis vinifera* and its translocation with in the vine. *Hilgardia* 28 : 625-45.

WEST, C.A. and PHINNEY, B.O. 1959. Gibberellin from flowering plants. I. Isolation and properties of gibberellin from *Phaseolus vulgaris* L. *J. Am. chem. Soc.* **81** : 2424-27.

WHALEY, W.G. and KEPHART, J. 1957. Effect of gibberellic acid on growth of maize roots. *Science* 125 : 234.

WHEELER, A.W. and HUMPHRIES, E.C. 1964. Separation of the effects of gibberellic acid on leaf and stem growth of dwarf french bean. *Nature, Lond* **202** : 616.

WITTWER, S.M. and BUKOVAC, M.J. 1957. Gibberellin effects on temperature and photoperiodic requirements for flowering of some plants. *Science* **126** : 30-31.

——— and ——— 1957. Gibberellin new chemical for crop production. *Q. Bull. Mich. agric. Stn* **30** : 460-94.

——— and ——— 1957c. Gibberellin and higher plants. Field observations with certain vegetable crops. *ibid.* **40** : 352-64.

——— and ——— 1958. The effect of gibberellins on economic crops. *Econ. Bot.* **12** : 213-55.

——— and ——— 1961. Gibberellin modification of flower sex expression in *Cucumis sativus* L. *Adv. Chem. Ser.* No. **28** : 80-88.

———, ——— SELL, H.M. and WELLER, L.E. 1957. Some effects of gibberellin on flowering and fruit setting. *Pl. Physiol.* **32** : 39-41.

———, ——— and ——— 1958. An appraisal of gibberellin for crop production. *Harmology* **2** : 3-6.

ZAURALOV, O.A. 1963. The influence of cooling on the growth of plants treated with gibberellin (Russian). *Fiziol. hast.* **10** : 602-05.

GOA UNIVERSITY LIBRARY
TALEIGAO GOA
Donation ACC No. 070
Name of Donour L. B. Afonso.